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Mulch and fertilizer effect on soil nutrient content, water conservation and oil palm growth

Rubén Ortiz[1], Enrique Villalobos[2], Olman Fernández[1]

Abstract

Field experiments were conducted in 1989 and 1990 to determine the effect of empty fruit bunches (EFB), and palm shell (PS) mulches and fertilizer (21-3-16-5-1) (F) on soil nutrient content, oil palm (*Elaeis guineensis* Jacq.) growth, midday relative water content (RWC) and abaxial stomatal conductance (C ab). A honeycomb experimental design with seven treatments, including EFB, PS and F applications and a tester, were used. The EFB increased soil P, K, and pH, improved soil moisture, and produced higher midday RWC and C ab values. Single and double layers of EFB plus F and the PS mulch increased oil palm growth during the rainy season. The EFB did not carry its beneficial water conservation effects to the second dry season, whereas PS maintained its effects through 1991.

Introduction

T he use of mulch has extensively proven to preserve soil moisture, reducing the soil temperature and increasing nutrient uptake and crop productivity (Simpson and Gumbs, 1986; Gallaher, 1977; Hartley, 1981). With the increasing cost of inorganic fertilizers, the use of oil palm by-products as mulch and sources of nutrients is an important alternative. Arokiasani (1969) evaluated methods of using EFB as fertilizer in oil palm. The application of EFB has been practiced as a mulch in oil palm field nurseries (Gunn, et al., 1961) and has shown beneficial effects on oil palm growth and yield increases in mature palms under different soils and rainfall regimes in Malaysia (Loong et al., 1987; Chan et al., 1980; Singh et al., 1976; and Khoo and Chew, 1969). Chiew and Weng (1989) reported increases in fresh fruit bunch (FFB) yield when EFB was applied at the time of field planting. These authors also indicated that EFB must be applied at planting to fully exploit its agronomic benefits as compared to EFB applied at the onset of maturity.

Palm shell is another by-product that can be used for mulch purposes. Approximately five tons of shell are obtained from sixty-six tons of FFB (Chan et al ., 1980). Palm shell is often used as a mulch in nursery polybags. Its beneficial effect is mainly due to better weed control and avoiding soil surface crusting.

Mulch and fertilizer applications may help improve the oil palm water status and its stomatal conductance during periods of water shortage. Villalobos et al. (1990) showed that the use of K fertilizer improved water status of mature oil palms under conditions of water stress. The purpose of this study was to evaluate the effect of oil palm empty fruit bunches, palm shell, and

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fertilizer on the soil nutrient content, oil palm growth and water conservation in juvenile oil palm plants.

Materials and methods

The experiment was started in Nicoya Farm, Quepos, Costa Rica in December 1989 on an Aquic Eutropept. A honeycomb statistical design with 28 replications was used. Seven treatments on the weeding circle were tested:

1. Tester, bare soil
2. Palm shell (PS)
3. Palm shell plus fertilizer (PS+F)
4. Fertilizer alone (F)
5. Empty fruit bunches (EFB)
6. EFB plus fertilizer (EFB+F)
7. Double EFB layer plus fertilizer (DEFB+F)

The fertilizer formula used was 21-3-16-5-1, applied at 85, 117, and 123 kg ha^{-1}. Applications took place 0, 150, and 240 days after the experiment was started on seven-month-old field palms. The PS and EFB were applied on the weeded circle, leaving a clear radius of 0.5 m of the inner circle for fertilizer application.

Empty fruit bunches were distributed in one layer around the plant for treatment 5 and 6 and two layers for the DEFB treatment. Palm shell was applied in a 5 cm thick layer. Soil sampling at 0-5, 5-10, 10-15, and 15-30 cm depth was made 0 and 120 days after treatment application (DAT). Palm growth measurements were taken from leaf number 1 at 0, 60, 120, 240, and 360 DAT. Mulch was applied at the beginning of the dry season in December 1989. A mean statistical analysis was carried out using a T test ($P<0.05$).

Abaxial stomatal conductance (C_{ab}) measurements were taken at midday from the midsection of the leaflets on the central part of leaf 9, using a diffusion porometer LI-700. Ten to fifteen readings were obtained from each plant. Five leaflets were used to determine the relative water content (RWC).

To determine the RWC the central portions of the leaflets were placed in sealed plastic bags (Zip-lock[R]) and kept in an ice chest. Later on the same day, twelve discs (25 mm in diameter, including the central vein) were obtained from each leaf sample. Fresh weight (FW) of the disc sample was recorded. The discs were then placed in a pan between a double layer of cheese cloth saturated with water. After two hours, the discs were superficially dried with paper towel and the sample turgid weight (TW) was recorded. The dry weight (DW) was obtained by drying the tissue for two days at 65°C in a forced convection oven. The RWC was calculated using the formula:

$$RWC = [(FW-DW) / (TW-DW)] \times 100$$

Soil moisture was determined using the gravimetric procedure by drying soil samples for two days at 65°C in a convection oven.

Results and discussion

Soil nutrient content and pH

pH. Higher pH values (0.11-0.7 units) were observed at 0-5 cm soil depth when EFB was applied as compared to the other treatments. A similar trend was observed at 5-10 and 10-15 cm depth (Fig.1). No differences were found at 15-30 cm depth.

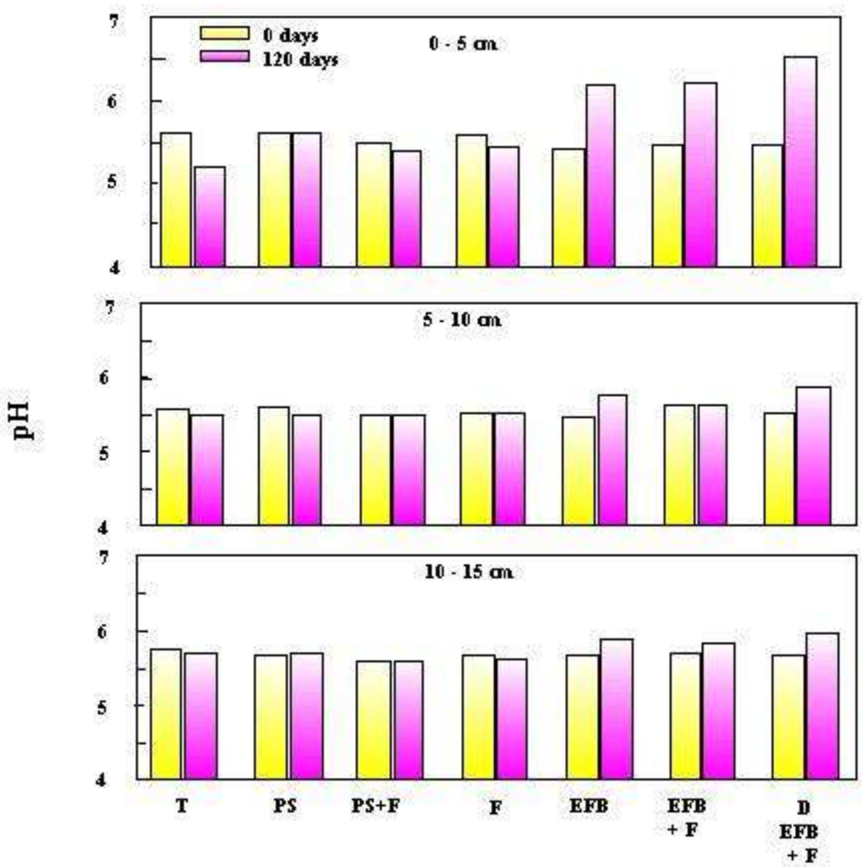

Fig. 1.Effect of empty fruit bunches, fertilizer and palm shell application on soil pH at different depths. Treatments: T=tester, PS=palm shell, F=fertilizer, EFB= empty fruit bunches, D= double

Phosphorus. Soil P content increased (0.35-5.5 mg kg^{-1}) at 0-5 cm depth when EFB was applied, as compared to the other treatments where little or no increase was observed (Fig. 2). Increases in soil P content were obtained at 5-10 and 10-15 cm depth for the treatments including EFB and/or fertilizer. No differences were found at 15-30 cm depth.

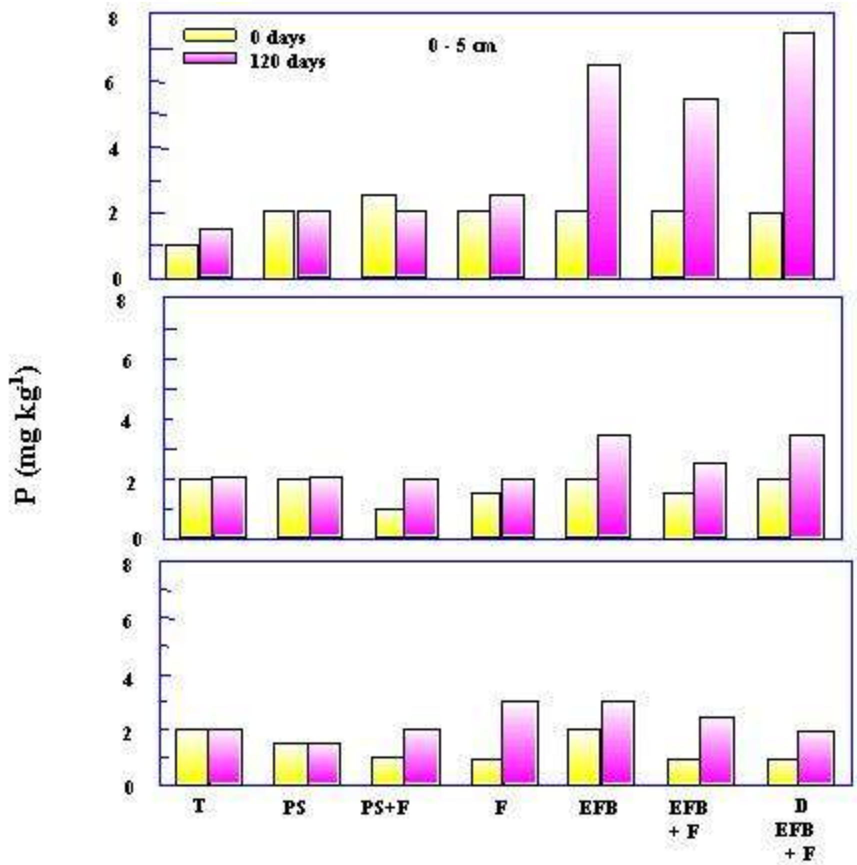

Fig. 2. Effect of empty fruit bunches, fertilizer and palm shell application on soil P content at different depths. Treatments: T=tester, PS=palm shell, F=fertilizer, EFB= empty fruit bunches, D= double

Potassium. A substantial increase in K content was observed at all soil depths when EFB was applied (Fig. 3). These results were similar to those of Arokiasani (1969) and Singh et al., (1976); who reported high K content in EFB. Uribe and Bernal (1973) determined that the EFB ash contained 30 to 35 per cent of K_2O. High amounts of K could be available for oil palm uptake 120 days after the application of EFB.

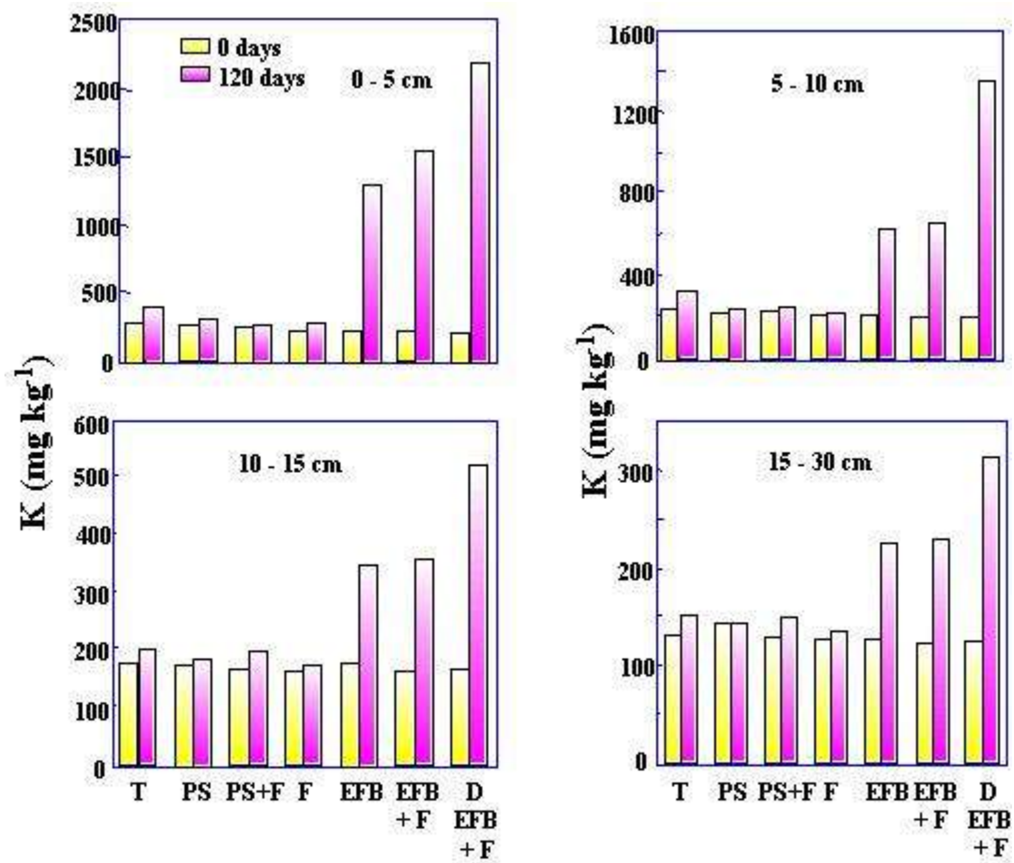

Fig. 3. Effect of empty fruit bunches, fertilizer and palm shell application on soil K content at different depths. Treatments: T=tester, PS=palm shell, F=fertilizer, EFB= empty fruit bunches, D= double

Calcium. Soil Ca content decreased in all treatments. However, a greater decrease was observed for the EFB treatments at 0-5 cm depth, where K content was highest. This indicated a possible inverse relationship between soil Ca and K supplied through EFB application. However, the reason why Ca content decreased is unknown.

Oil palm growth

The highest petiole cross section (PxS) values were found for DEFB+F, followed by EFB+F, PS, and EFB treatments, 120 DAT (Table 1). Similar results were observed for rachis length, petiole cross section, and leaf area 120 DAT. Petiole cross section tended to be greater when mulch was applied 240 DAT. PXS and leaf emission rate were lower in the tester as compared to all the other treatments. Rachis length was shorter and leaf area lower for treatments EFB+F and DEFB+F at the same date (Table 1).

The application of DEFB+F showed highest PXS and rachis length values as compared to other treatments 360 DAT (Table 1). In general, DEFB+F showed the highest values for oil palm growth variables. It was closely followed by EFB+F and PS application treatments. Basically, all mulch and fertilizer treatments were better than the tester.

Table 1. Growth measurements of young oil palms at 60, 120, 240, and 360 days after application (DAT) of empty fruit bunches (EFB), palm shell (PS), and fertilizer (F)

dat*	Treatment	Rachis length -cm-	Petiole cross section, cm^2	Leaf area $-m^2-$	Leaf emission rate $month^{-1}$
60	Tester	169.5	3.27 b	1.56	
	PS	172.7	3.52 ab	1.62	
	PS + F	170.3	3.28 b	1.57	
	F	173.1	3.26 b	1.62	
	EFB	173.8	3.48 ab	1.65	
	EFB + F	176.3	3.53 ab	1.6	
	DEFB + F	171.7	3.69 a	1.59	
120	Tester	183.7 abc	2.88 c	1.41 b	
	PS	188.9 a	3.05 abc	1.55 a	
	PS + F	180.5 bc	2.99 b	1.41 b	
	PS + F	180.5 bc	2.99 bc	1.41 b	
	F	179.2 c	3.03 abc	1.43 ab	
	EFB	186.1 ab	3.13 ab	1.45 ab	
	EFB + F	183.0 abc	3.17 ab	1.47 a	
	DEFB + F	184.6 abc	3.24 a	1.55 a	
240	Tester	198.2 a	3.62 b	1.92 ab	2.44b
	PS	194.5 a	3.80 ab	2.04 a	2.66 a
	PS + F	189.5 ab	3.72 ab	1.93 ab	2.63 a
	F	189.1 ab	3.59 b	1.91 ab	2.61 a
	EFB	192.5 ab	3.76 ab	1.89 ab	2.53 ab
	EFB + F	180.4 b	3.82 a	1.76 b	2.52 ab
	DEFB + F	182.8 b	3.70 ab	1.81 b	2.65 a
360	Tester	246.1 c	4.61 c	2.82 b	3.78 bc
	PS	263.2 ab	4.94 abc	3.08 a	3.90 abc
	PS + F	258.7 ab	4.92 abc	2.89 ab	4.00 a
	F	258.5 ab	4.87 abc	2.93 ab	4.02 a
	EFB	251.2 bc	4.65 bc	2.79 b	3.72 c
	EFB + F	255.0 ab	4.97 ab	2.86 ab	3.95 ab
	DEFB + F	264.5 a	5.14 a	3.01 a	4.05 a

* DAT= days after treatment application.

Values within a column followed by the a same letter are not significantly different by the t test ($P<0.05$).

The application of EFB showed a slightly higher overall PxS value as compared to PS and was greater than the tester. However, PS application showed a greater overall leaf area and leaf emission rate as compared to the application of EFB and the tester, respectively (Table 2). Simultaneously, higher oil palm growth was observed when fertilizer was applied, regardless of the mulching treatments, as compared to treatments where fertilizer was not applied (Table 2). Visual observations indicated that PS was still present in the weeding circle 360 DAT, whereas most of the EFB were already decomposed after the first rainy season.

Table 2. Overall effect of mulch and fertilizer application on oil palm growth

Variable	Treatment	Mulch				Overall average of fertilizer effect	
		None	Palm shell	EFB	Double EFB		
P x S							
	No Fertilizer	3.7	3.93	3.85	3.85	3.83	
	Fertilizer	3.83	3.88	3.99	4.03	3.9	(3.91)
	Overall Average of Effect of Mulch	3.76	3.9	3.92	3.94	3.87	
Leaf area *							
	No Fertilizer	2.05	2.22	2.04	2.04	2.1	
	Fertilizer	2.09	2.08	2.03	2.12	2.07	(2.10)
	Overall Average of Effect of Mulch	2.07	2.15	2.035	2.08	2.085	
Leaf emission rate **							
	No Fertilizer	3.11	3.28	3.12	3.12	3.17	
	Fertilizer	3.32	3.32	3.24	3.35	3.29	(3.33)
	Overall Average of Effect of Mulch	3.22	3.3	3.18	3.24	3.23	

* Average of 120, 240 and 360 days after treatment application.
** Average of 240 and 360 days after treatment application.
( ) Overall average of effect of fertilizer when DEFB was tested. EFB=empty fruit bunch

Water relations

The EFB application improved soil moisture during the first dry spell similarly to what has been observed with the use of other mulch types (Daisley et al., 1988; Simpson and Gumbs, 1986) (Table 3). However, EFB material decomposed during the following rainy season and did not carry its beneficial effect on soil moisture content to the next dry season. On the other hand, the application of palm shell slightly improved soil moisture in 1990 and maintained its effectiveness through 1991 (Table 3).

Table 3. Soil moisture content (% dry basis) around palms under different palm shell (PS), empty fruit bunches (EFB), and fertilizer (F) application treatments

Means	1990		1991
	Feb.13 60 DAT	Mar.6 87 DAT	Jan.9 396 DAT
Tester	28.5	24.7	27.0
PS	30.0	27.3	32.0
PS+F	22.5	29.3	39.1
F	16.3	20.6	23.5
EFB	38.0	32.6	25.3
EFB + F	36.3	35.1	26.6
Double EFB + F	35.1	35.6	27.6

Composite soil samples were taken at 1.5 m from the trunk at 0-15 cm depth. DAT= Days after treatment application

The overall values of RWC in the treated palms during the period in which soil water became limiting were greater than those in the plants that did not receive EFB (Fig. 4). The application of fertilizer improved the plant RWC, but to a lesser extent than the EFB mulch application (Fig. 5). However, the C ab values were not affected by the fertilizer treatment, in agreement with what was found in adult palms by Villalobos et al., (1990). The C_{ab} was improved by the mulching treatments except at the time of greater water shortage (Fig. 4).

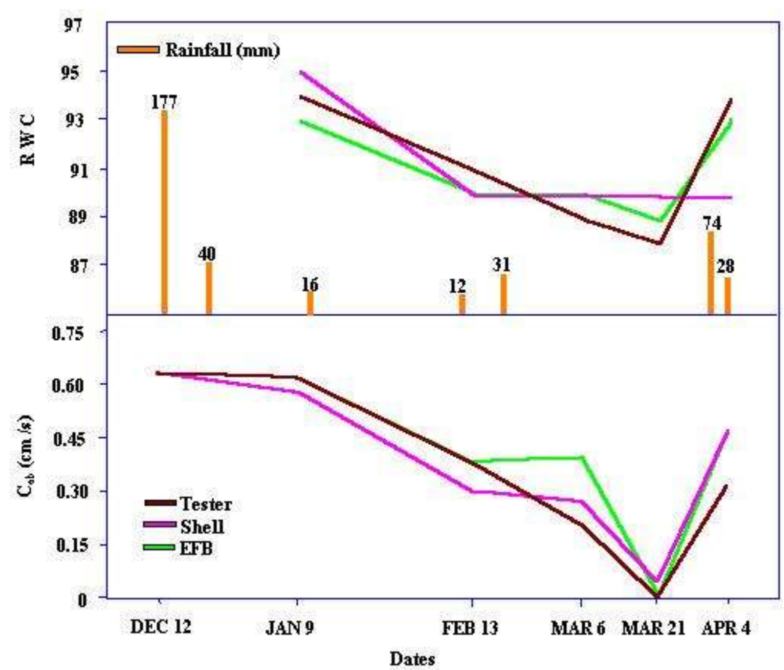

Fig. 4. Relative water content (RWC) and abaxial stomatal conductance (C_{ab}) overall values as affected by empty fruit bunch (EFB) and palm shell mulch application

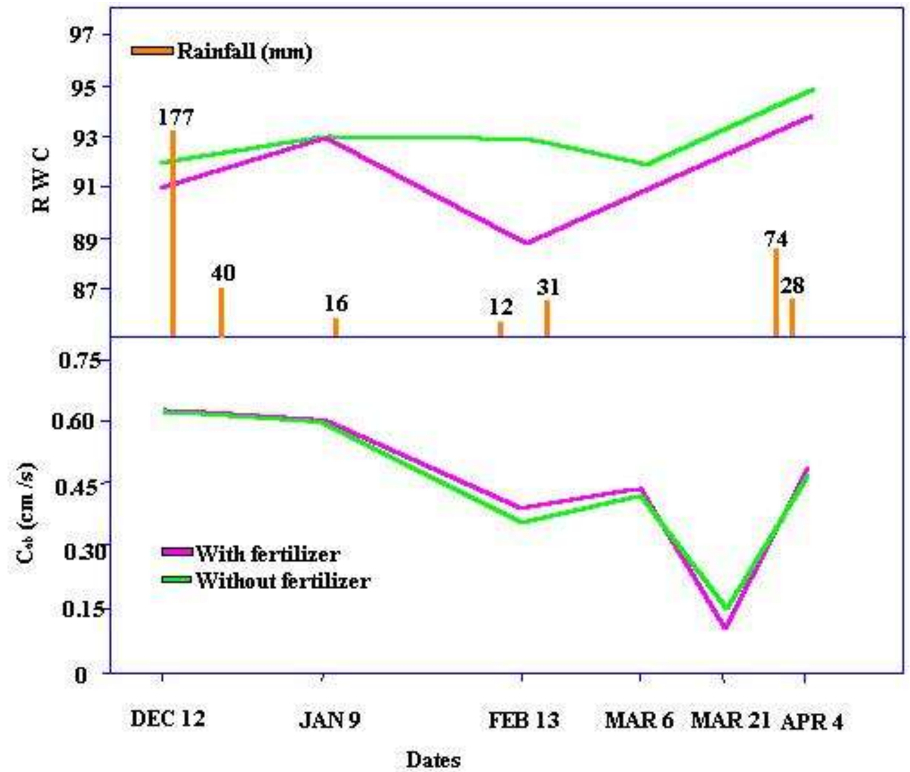

Fig. 5. Stomatal conductance (C_{ab}) and relative water content (RWC) of young oil palms as affected by fertilizer application (1989-1990).

Conclusions

Oil palm EFB supplied high amounts of K to the soil. Soil P and pH increased with the application of EFB. The application of a double layer of EFB+F increased oil palm growth 360 DAT. A similar result was observed when EFB+F and PS mulch were applied. Overall plant growth was greater when PS was applied, as compared to EFB and no applications. The fertilizer application (overall) showed a positive effect on oil palm growth.

The use of EFB and PS as weeding circle mulch improved soil moisture. Relative water content values in oil palm should be interpreted with caution, since a stomatal control of the plant's water status under conditions of water stress has been recently demonstrated (Villalobos et al., 1991). This implies that the stomatal closure may induce a high RWC value. However, since the greater values of RWC corresponded to greater C_{ab} values (palms with EFB mulch), it can be concluded that the increase in turgor was a response to the application of EFB mulch. Fertilizer applications induced higher RWC but showed no differences in C_{ab} .

The application of EFB mulch is recommended to alleviate the problem of water stress and to increase soil nutrient content in areas exposed to water deficit, at least during the first dry season after field transplanting, when the palms are more susceptible to water deficit.

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Early growth of young oil palms under different leguminous cover crops

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Abstract

The effect of four different cover crop species (*Flemingia congesta* (Roxb), *Arachis pintoi*. L, *Pueraria phaseoloides* (Roxb) Benth and *Desmodium ovalifolium* Wall) on early oil palm growth was evaluated. Oil palm growth as affected by the leguminous cover crops ranked as follows from best to poorest after 450 days: *F. congesta*, *P. phaseoloides* , *D. ovalifolium* and *A. pinto* . The magnitude of the differences on oil palm growth under these intercropping system will be the subject of future research.

Introduction

Oil palm (*Elaeis guineensis* Jacq.) is an important crop in Costa Rica. Traditionally, kudzu (*Pueraria phaseoloides* (Roxb) Benth L.) has been the most commonly used cover crop in oil palm, in Costa Rica. Leguminous cover crops are planted to protect the soil surface from erosion, help control weeds and obtain organic N from biological fixation. Agamuthu and Broughton (1985) found that the total benefits of leguminous covers intercropped with oil palm amount to 239 kg N ha^{-1} $year^{-1}$. Turner and Gillbanks (1974) indicated that some desirable cover crop characteristics are:

1. Vigorous growth.
2. Easy to maintain.
3. Strong root system.
4. Low competition with oil palm.
5. Low lying.
6. Beneficial to soil nutrient content.

Bourgoing (1990) pointed out that the longevity of a cover crop and its positive effect on coconut yield will depend on proper soil preparation and the right choice of the cover crop species. Oil palm growth and yield vary under different types of cover crops (Turner and Gillbanks, 1974). The purpose of this study was to evaluate the effect of four different cover crops on early oil palm growth on the southern Pacific coast of Costa Rica.

Material and methods

A field experiment was conducted using one-year-old oil palm (Deli x Calabar) nursery palms field planted in June 1990. A completely randomized design with four replications and five treatments was used.

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Treatments were 1. A control (bare soil). 2. *Pueraria phaseoloides* (Roxb.) Benth. 3. *Flemingia congesta* Roxb. 4. *Desmodium ovalifolium* Wall and 5. *Arachis pintoi* L.

Each leguminous cover crop was planted between the oil palm rows which were set apart 9.0 m on an equilateral triangular pattern. Treatments were randomly allocated in 20 plots. Each plot covered an area of 0.14 ha and contained 20 palms.

Growth measurements (Corley and Breure, 1981) were taken at 180, 270, 360, and 450 days after cover crop planting (DAP). Due to its high vegetative growth, *F. congesta* was pruned to 100 cm height and *D. ovalifolium* to 40 cm one year after cover crop planting. The vegetative material originated from such pruning was applied to the palm weeded circles.

Results and discussions

Growth measurements up to 450 DAP are shown in Table 1. Cover crops had a major influence on the rachis length and petiole cross section (PXS). The *F. congesta* treatment rachis length was higher as compared to all other treatments, but similar to *P. phaseoloides* from 180 to 360 DAP. No statistical differences were found 450 DAP, but a trend similar to previous measurements was observed.

The *F. congesta* treatment showed the highest PxS values as compared to the other treatments 360 and 450 DAP. These values were statistically similar to *P. phaseoloides* and the tester (bare soil) and greater than the *D. ovalifolium* and *A. pintoi* treatments. Similar behavior was observed for total number of leaves and leaf length, 450 DAP. In general, the opposite effect was found for number of leaflets per rachis meter from 180 to 360 DAP. All this indicated that the oil palm suffered from etiolation due to the *F. congesta* competition.

Oil palm growth measurements showed the following results for most variables: *F. congesta P. phaseoloides* Tester *D. ovalifolium* and *A. pintoi*. There was a slight trend showing better oil palm growth in *D. ovalifolium* treatment as compared to *A. pintoi*.

These results suggested that *F. congesta* as a cover crop leads to improved palm growth in spite of a deleterious effect of slight etiolation due to competition for light. The magnitude of the potential beneficial effects are not known, but will be the subject of future research. Similarly, the mechanisms for the apparent negative effects of *D. ovalifolium* and *A. pintoi* on oil palm growth need to be identified.

Table 1. Oil palm growth as affected by cover crop 180, 270, 360, and 450 days after treatment application (DAP) (cover crop planting)

Days after planting	**Treatments**	**Bulb Diameter (cm)**	**Rachis length (cm)**	**Petiole length (cm)**	**Petiole cross section (cm^2)**	**Leaflets**				**Leaf**			
						Total	**Length (cm)**	**Width (cm)**	**/meter rachis**	**Length (cm)**	**Area (m^2)**	**Emission**	**Total**
180	*Arachis*		131.4b	22.9	2.13	155.1	41.9	2.9	118.5	154.3b	1.02bc		19.42
	Flemingia		142.4a	24.9	2.29	159.7	45.1	3.1	112.5	167.2a	1.19a		20
	Desmodium		129.6b	21.8	2.06	149.2	40.9	2.9	115.7	151.4b	0.95c		18.7
	Pueraria		142.3a	24.3	2.27	160.7	44.8	3.1	113.3	166.6a	1.17ab		19.8
	Tester		136.3ab	23.6	2.37	157.9	42.9	3	116.5	159.9ab	1.08abc		19.35
270	*Arachis*	27.69	158.8c	22.17bc	2.67	182.99	46.59	3.34	115.59a	180.99c	1.51	8.48	26.3
	Flemingia	29.17	177.0a	26.32a	3.04	188.13	48.92	3.5	107.11b	203.26a	1.71	8.73	26.6
	Desmodium	26.98	157.0c	21.07c	2.68	177.73	46.3	3.32	113.57a	178.06c	1.45	8.53	25.5
	Pueraria	29.88	172.3ab	23.81b	2.91	190.13	48.31	3.41	110.79ab	196.11ab	1.66	8.75	26.8
	Tester	29.16	163.9bc	22.84bc	2.98	185.85	47.13	3.4	114.09a	186.74bc	1.58	8.55	26.1
360	*Arachis*		180.0b	27.6b	3.3bc	199.8	52.2	3.3	111.7a	207.6b	1.8	8.7	27.2
	Flemingia		214.5a	34.8a	3.7a	206.2	56.5	3.6	97.5b	249.3a	2.2	8.4	27.6
	Desmodium		183.5b	26.9b	3.2c	197.2	52.8	3.3	108.0a	210.5b	1.8	8.7	27
	Pueraria		198.4ab	28.6b	3.6ab	206.6	54.5	3.4	104.7ab	227.0ab	2.1	8.7	27.5
	Tester		186.7b	26.8b	3.6ab	202.7	53.5	3.3	109.4a	213.8b	1.9	8.8	27.7
450	*Arachis*		213.6	27.7b	3.9b	215	56.7	3.9b	101.2	241.4	2.6	9.7a	28.5b
	Flemingia		236.5	31.5a	4.6a	221	58.1	4.3a	94.5	268	2.9	9.0b	29.5a
	Desmodium		217.7	27.7b	4.0b	212	56.5	3.9b	98.2	245.3	2.5	9.7a	28.5b
	Pueraria		231.4	30.1ab	4.3ab	220	58.4	4.0b	95.9	261.6	2.7	9.6a	29.6a
	Tester		221	27.7b	4.3ab	218	57.4	4.0b	99.4	248.6	2.8	9.8a	30.0a

Values within a column followed by the same letter are not significantly different at the 0.05 probability level by the FPLSD test.

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Mulch and fertilizer effect on soil nutrient content, water conservation and oil palm growth

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Abstract

Field experiments were conducted in 1989 and 1990 to determine the effect of empty fruit bunches (EFB), and palm shell (PS) mulches and fertilizer (21-3-16-5-1) (F) on soil nutrient content, oil palm (*Elaeis guineensis* Jacq.) growth, midday relative water content (RWC) and abaxial stomatal conductance (C ab). A honeycomb experimental design with seven treatments, including EFB, PS and F applications and a tester, were used. The EFB increased soil P, K, and pH, improved soil moisture, and produced higher midday RWC and C ab values. Single and double layers of EFB plus F and the PS mulch increased oil palm growth during the rainy season. The EFB did not carry its beneficial water conservation effects to the second dry season, whereas PS maintained its effects through 1991.

Introduction

T he use of mulch has extensively proven to preserve soil moisture, reducing the soil temperature and increasing nutrient uptake and crop productivity (Simpson and Gumbs, 1986; Gallaher, 1977; Hartley, 1981). With the increasing cost of inorganic fertilizers, the use of oil palm by-products as mulch and sources of nutrients is an important alternative. Arokiasani (1969) evaluated methods of using EFB as fertilizer in oil palm. The application of EFB has been practiced as a mulch in oil palm field nurseries (Gunn, et al., 1961) and has shown beneficial effects on oil palm growth and yield increases in mature palms under different soils and rainfall regimes in Malaysia (Loong et al., 1987; Chan et al., 1980; Singh et al., 1976; and Khoo and Chew, 1969). Chiew and Weng (1989) reported increases in fresh fruit bunch (FFB) yield when EFB was applied at the time of field planting. These authors also indicated that EFB must be applied at planting to fully exploit its agronomic benefits as compared to EFB applied at the onset of maturity.

Palm shell is another by-product that can be used for mulch purposes. Approximately five tons of shell are obtained from sixty-six tons of FFB (Chan et al ., 1980). Palm shell is often used as a mulch in nursery polybags. Its beneficial effect is mainly due to better weed control and avoiding soil surface crusting.

Mulch and fertilizer applications may help improve the oil palm water status and its stomatal conductance during periods of water shortage. Villalobos et al. (1990) showed that the use of K fertilizer improved water status of mature oil palms under conditions of water stress. The purpose of this study was to evaluate the effect of oil palm empty fruit bunches, palm shell, and

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fertilizer on the soil nutrient content, oil palm growth and water conservation in juvenile oil palm plants.

Materials and methods

The experiment was started in Nicoya Farm, Quepos, Costa Rica in December 1989 on an Aquic Eutropept. A honeycomb statistical design with 28 replications was used. Seven treatments on the weeding circle were tested:

1. Tester, bare soil
2. Palm shell (PS)
3. Palm shell plus fertilizer (PS+F)
4. Fertilizer alone (F)
5. Empty fruit bunches (EFB)
6. EFB plus fertilizer (EFB+F)
7. Double EFB layer plus fertilizer (DEFB+F)

The fertilizer formula used was 21-3-16-5-1, applied at 85, 117, and 123 kg ha^{-1}. Applications took place 0, 150, and 240 days after the experiment was started on seven-month-old field palms. The PS and EFB were applied on the weeded circle, leaving a clear radius of 0.5 m of the inner circle for fertilizer application.

Empty fruit bunches were distributed in one layer around the plant for treatment 5 and 6 and two layers for the DEFB treatment. Palm shell was applied in a 5 cm thick layer. Soil sampling at 0-5, 5-10, 10-15, and 15-30 cm depth was made 0 and 120 days after treatment application (DAT). Palm growth measurements were taken from leaf number 1 at 0, 60, 120, 240, and 360 DAT. Mulch was applied at the beginning of the dry season in December 1989. A mean statistical analysis was carried out using a T test ($P<0.05$).

Abaxial stomatal conductance (C_{ab}) measurements were taken at midday from the midsection of the leaflets on the central part of leaf 9, using a diffusion porometer LI-700. Ten to fifteen readings were obtained from each plant. Five leaflets were used to determine the relative water content (RWC).

To determine the RWC the central portions of the leaflets were placed in sealed plastic bags (Zip-lock^{R}) and kept in an ice chest. Later on the same day, twelve discs (25 mm in diameter, including the central vein) were obtained from each leaf sample. Fresh weight (FW) of the disc sample was recorded. The discs were then placed in a pan between a double layer of cheese cloth saturated with water. After two hours, the discs were superficially dried with paper towel and the sample turgid weight (TW) was recorded. The dry weight (DW) was obtained by drying the tissue for two days at 65°C in a forced convection oven. The RWC was calculated using the formula:

$$RWC = [(FW-DW) / (TW-DW)] \times 100$$

Soil moisture was determined using the gravimetric procedure by drying soil samples for two days at 65°C in a convection oven.

Results and discussion

Soil nutrient content and pH

pH. Higher pH values (0.11-0.7 units) were observed at 0-5 cm soil depth when EFB was applied as compared to the other treatments. A similar trend was observed at 5-10 and 10-15 cm depth (Fig.1). No differences were found at 15-30 cm depth.

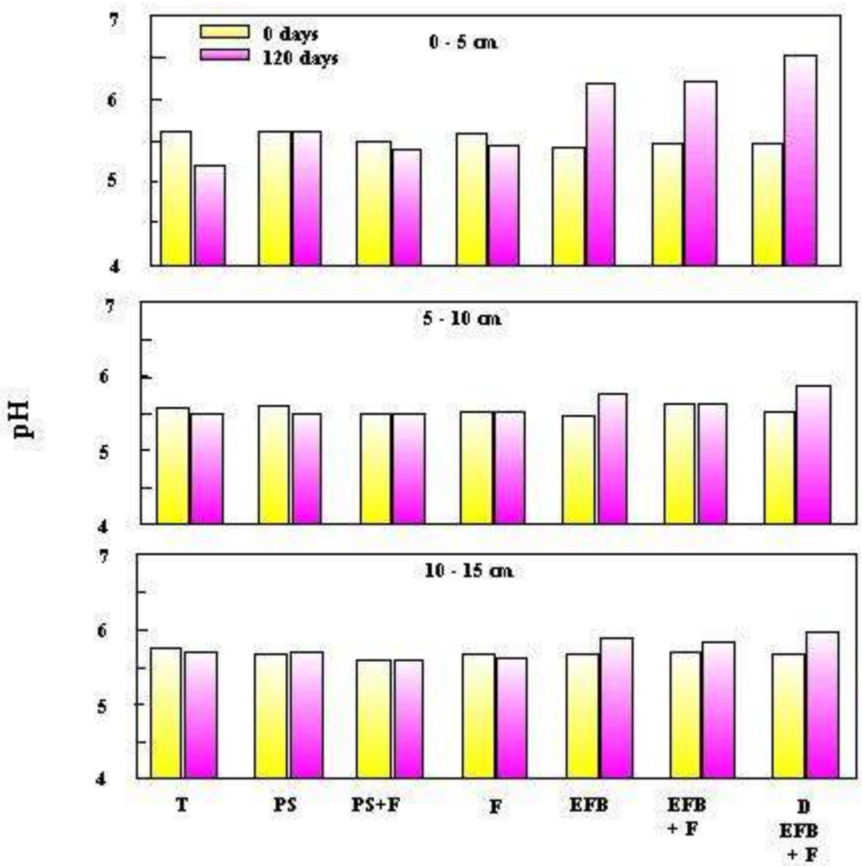

Fig. 1.Effect of empty fruit bunches, fertilizer and palm shell application on soil pH at different depths. Treatments: T=tester, PS=palm shell, F=fertilizer, EFB= empty fruit bunches, D= double

Phosphorus. Soil P content increased (0.35-5.5 mg kg^{-1}) at 0-5 cm depth when EFB was applied, as compared to the other treatments where little or no increase was observed (Fig. 2). Increases in soil P content were obtained at 5-10 and 10-15 cm depth for the treatments including EFB and/or fertilizer. No differences were found at 15-30 cm depth.

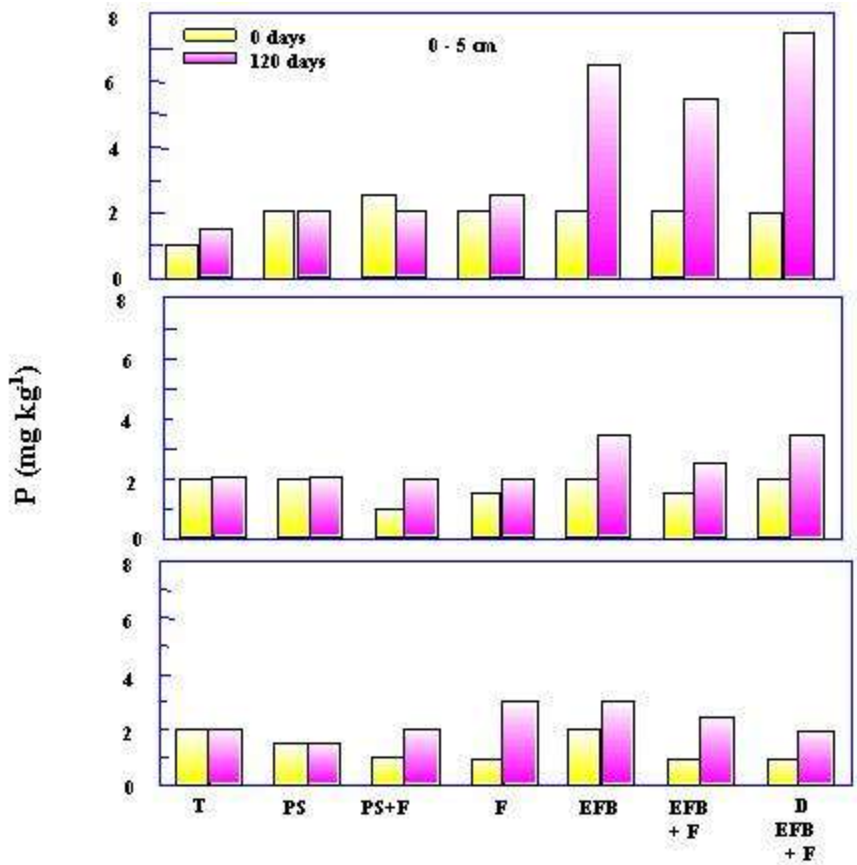

Fig. 2. Effect of empty fruit bunches, fertilizer and palm shell application on soil P content at different depths. Treatments: T=tester, PS=palm shell, F=fertilizer, EFB= empty fruit bunches, D= double

Potassium. A substantial increase in K content was observed at all soil depths when EFB was applied (Fig. 3). These results were similar to those of Arokiasani (1969) and Singh et al., (1976); who reported high K content in EFB. Uribe and Bernal (1973) determined that the EFB ash contained 30 to 35 per cent of K_2O. High amounts of K could be available for oil palm uptake 120 days after the application of EFB.

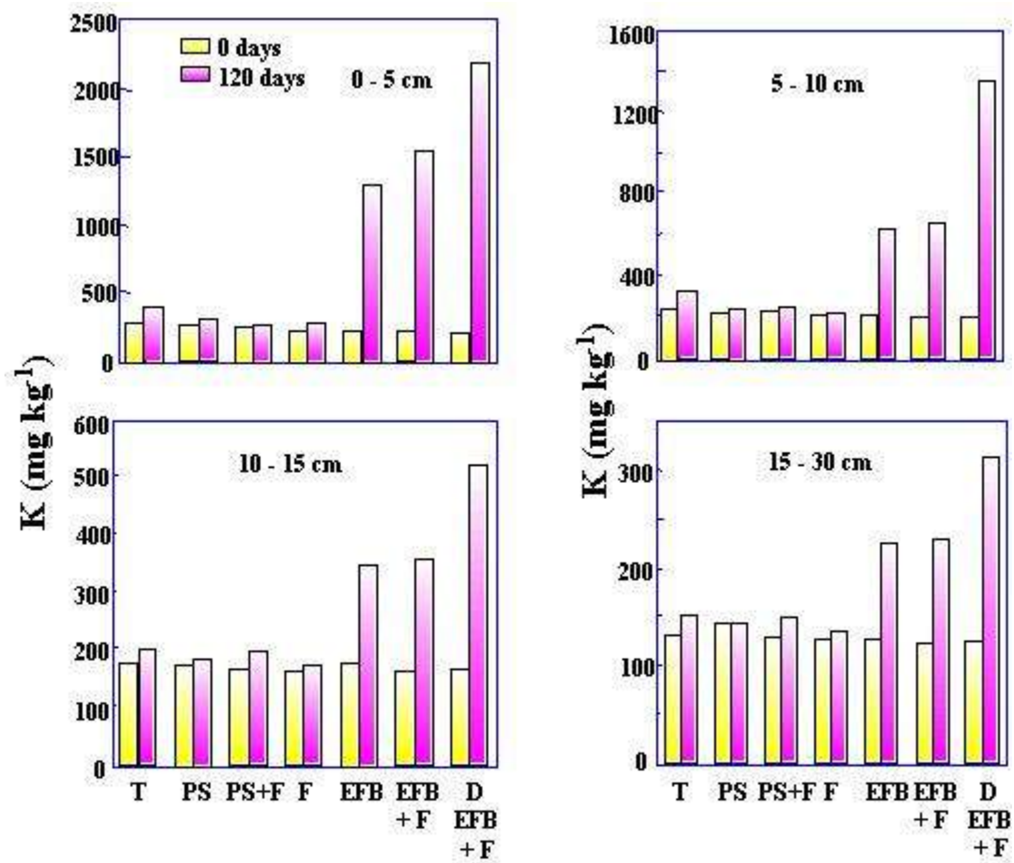

Fig. 3. Effect of empty fruit bunches, fertilizer and palm shell application on soil K content at different depths. Treatments: T=tester, PS=palm shell, F=fertilizer, EFB= empty fruit bunches, D= double

Calcium. Soil Ca content decreased in all treatments. However, a greater decrease was observed for the EFB treatments at 0-5 cm depth, where K content was highest. This indicated a possible inverse relationship between soil Ca and K supplied through EFB application. However, the reason why Ca content decreased is unknown.

Oil palm growth

The highest petiole cross section (PxS) values were found for DEFB+F, followed by EFB+F, PS, and EFB treatments, 120 DAT (Table 1). Similar results were observed for rachis length, petiole cross section, and leaf area 120 DAT. Petiole cross section tended to be greater when mulch was applied 240 DAT. PXS and leaf emission rate were lower in the tester as compared to all the other treatments. Rachis length was shorter and leaf area lower for treatments EFB+F and DEFB+F at the same date (Table 1).

The application of DEFB+F showed highest PXS and rachis length values as compared to other treatments 360 DAT (Table 1). In general, DEFB+F showed the highest values for oil palm growth variables. It was closely followed by EFB+F and PS application treatments. Basically, all mulch and fertilizer treatments were better than the tester.

Table 1. Growth measurements of young oil palms at 60, 120, 240, and 360 days after application (DAT) of empty fruit bunches (EFB), palm shell (PS), and fertilizer (F)

dat*	Treatment	Rachis length -cm-	Petiole cross section, cm^2	Leaf area -m^2-	Leaf emission rate $month^{-1}$
60	Tester	169.5	3.27 b	1.56	
	PS	172.7	3.52 ab	1.62	
	PS + F	170.3	3.28 b	1.57	
	F	173.1	3.26 b	1.62	
	EFB	173.8	3.48 ab	1.65	
	EFB + F	176.3	3.53 ab	1.6	
	DEFB + F	171.7	3.69 a	1.59	
120	Tester	183.7 abc	2.88 c	1.41 b	
	PS	188.9 a	3.05 abc	1.55 a	
	PS + F	180.5 bc	2.99 b	1.41 b	
	PS + F	180.5 bc	2.99 bc	1.41 b	
	F	179.2 c	3.03 abc	1.43 ab	
	EFB	186.1 ab	3.13 ab	1.45 ab	
	EFB + F	183.0 abc	3.17 ab	1.47 a	
	DEFB + F	184.6 abc	3.24 a	1.55 a	
240	Tester	198.2 a	3.62 b	1.92 ab	2.44b
	PS	194.5 a	3.80 ab	2.04 a	2.66 a
	PS + F	189.5 ab	3.72 ab	1.93 ab	2.63 a
	F	189.1 ab	3.59 b	1.91 ab	2.61 a
	EFB	192.5 ab	3.76 ab	1.89 ab	2.53 ab
	EFB + F	180.4 b	3.82 a	1.76 b	2.52 ab
	DEFB + F	182.8 b	3.70 ab	1.81 b	2.65 a
360	Tester	246.1 c	4.61 c	2.82 b	3.78 bc
	PS	263.2 ab	4.94 abc	3.08 a	3.90 abc
	PS + F	258.7 ab	4.92 abc	2.89 ab	4.00 a
	F	258.5 ab	4.87 abc	2.93 ab	4.02 a
	EFB	251.2 bc	4.65 bc	2.79 b	3.72 c
	EFB + F	255.0 ab	4.97 ab	2.86 ab	3.95 ab
	DEFB + F	264.5 a	5.14 a	3.01 a	4.05 a

* DAT= days after treatment application.

Values within a column followed by the a same letter are not significantly different by the t test ($P<0.05$).

The application of EFB showed a slightly higher overall PxS value as compared to PS and was greater than the tester. However, PS application showed a greater overall leaf area and leaf emission rate as compared to the application of EFB and the tester, respectively (Table 2). Simultaneously, higher oil palm growth was observed when fertilizer was applied, regardless of the mulching treatments, as compared to treatments where fertilizer was not applied (Table 2). Visual observations indicated that PS was still present in the weeding circle 360 DAT, whereas most of the EFB were already decomposed after the first rainy season.

Table 2. Overall effect of mulch and fertilizer application on oil palm growth

Variable	Treatment	Mulch				Overall average of fertilizer effect	
		None	Palm shell	EFB	Double EFB		
P x S							
	No Fertilizer	3.7	3.93	3.85	3.85	3.83	
	Fertilizer	3.83	3.88	3.99	4.03	3.9	(3.91)
	Overall Average of Effect of Mulch	3.76	3.9	3.92	3.94	3.87	
Leaf area *							
	No Fertilizer	2.05	2.22	2.04	2.04	2.1	
	Fertilizer	2.09	2.08	2.03	2.12	2.07	(2.10)
	Overall Average of Effect of Mulch	2.07	2.15	2.035	2.08	2.085	
Leaf emission rate **							
	No Fertilizer	3.11	3.28	3.12	3.12	3.17	
	Fertilizer	3.32	3.32	3.24	3.35	3.29	(3.33)
	Overall Average of Effect of Mulch	3.22	3.3	3.18	3.24	3.23	

* Average of 120, 240 and 360 days after treatment application.
** Average of 240 and 360 days after treatment application.
( ) Overall average of effect of fertilizer when DEFB was tested. EFB=empty fruit bunch

Water relations

The EFB application improved soil moisture during the first dry spell similarly to what has been observed with the use of other mulch types (Daisley et al., 1988; Simpson and Gumbs, 1986) (Table 3). However, EFB material decomposed during the following rainy season and did not carry its beneficial effect on soil moisture content to the next dry season. On the other hand, the application of palm shell slightly improved soil moisture in 1990 and maintained its effectiveness through 1991 (Table 3).

Table 3. Soil moisture content (% dry basis) around palms under different palm shell (PS), empty fruit bunches (EFB), and fertilizer (F) application treatments

Means	1990		1991
	Feb.13 60 DAT	Mar.6 87 DAT	Jan.9 396 DAT
Tester	28.5	24.7	27.0
PS	30.0	27.3	32.0
PS+F	22.5	29.3	39.1
F	16.3	20.6	23.5
EFB	38.0	32.6	25.3
EFB + F	36.3	35.1	26.6
Double EFB + F	35.1	35.6	27.6

Composite soil samples were taken at 1.5 m from the trunk at 0-15 cm depth. DAT= Days after treatment application

The overall values of RWC in the treated palms during the period in which soil water became limiting were greater than those in the plants that did not receive EFB (Fig. 4). The application of fertilizer improved the plant RWC, but to a lesser extent than the EFB mulch application (Fig. 5). However, the C ab values were not affected by the fertilizer treatment, in agreement with what was found in adult palms by Villalobos et al., (1990). The C_{ab} was improved by the mulching treatments except at the time of greater water shortage (Fig. 4).

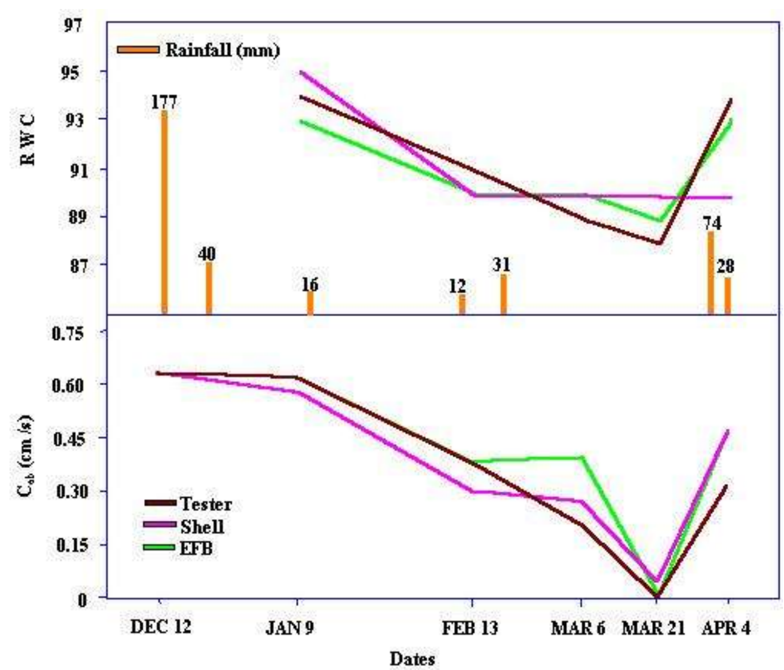

Fig. 4. Relative water content (RWC) and abaxial stomatal conductance (C_{ab}) overall values as affected by empty fruit bunch (EFB) and palm shell mulch application

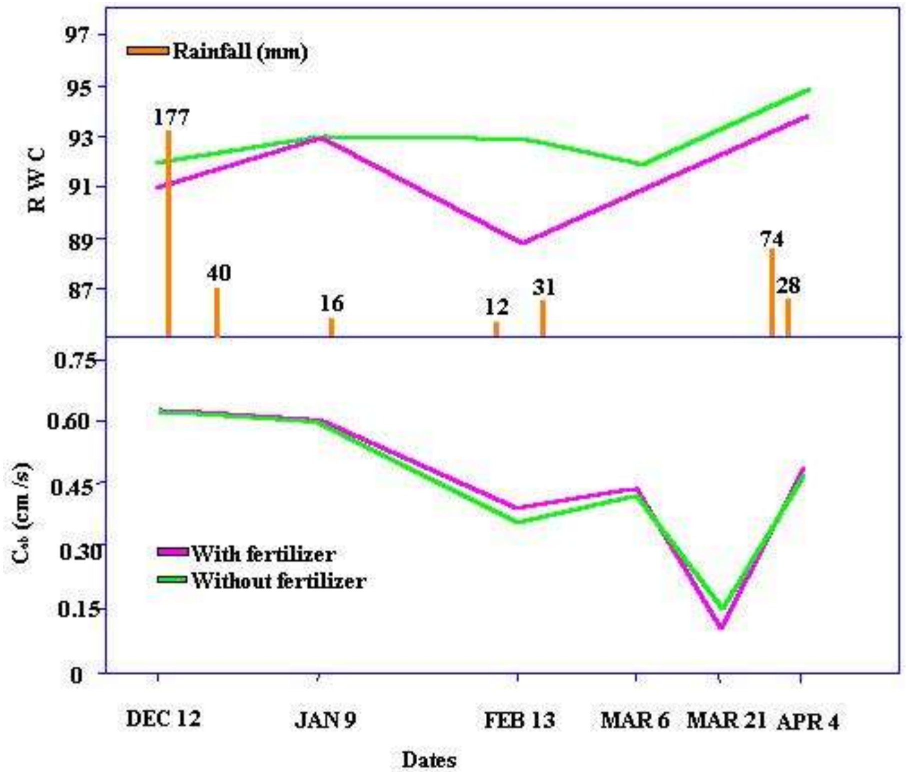

Fig. 5. Stomatal conductance (C_{ab}) and relative water content (RWC) of young oil palms as affected by fertilizer application (1989-1990).

Conclusions

Oil palm EFB supplied high amounts of K to the soil. Soil P and pH increased with the application of EFB. The application of a double layer of EFB+F increased oil palm growth 360 DAT. A similar result was observed when EFB+F and PS mulch were applied. Overall plant growth was greater when PS was applied, as compared to EFB and no applications. The fertilizer application (overall) showed a positive effect on oil palm growth.

The use of EFB and PS as weeding circle mulch improved soil moisture. Relative water content values in oil palm should be interpreted with caution, since a stomatal control of the plant's water status under conditions of water stress has been recently demonstrated (Villalobos et al., 1991). This implies that the stomatal closure may induce a high RWC value. However, since the greater values of RWC corresponded to greater C_{ab} values (palms with EFB mulch), it can be concluded that the increase in turgor was a response to the application of EFB mulch. Fertilizer applications induced higher RWC but showed no differences in C_{ab} .

The application of EFB mulch is recommended to alleviate the problem of water stress and to increase soil nutrient content in areas exposed to water deficit, at least during the first dry season after field transplanting, when the palms are more susceptible to water deficit.

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