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Oil palm root development as a response to mineral and organic nutrition in soils with prevalence of spear rots

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Abstract

Soil from an area where bud rots (PC = pudriciones del cogollo) were prevalent was amended with organic and mineral fertilizers to study the dynamic of the root system of young oil palms. In-growth bags made of a slow-degrading fabric containing the treatments were buried (30 cm) close to the palms. Soils from two sites were used, the first being a plot where PC incidence was high, and the other was the control with low incidence of PC. The soil from site one was amended with either of three treatments: 1) control, 2) amended with 100 g of chemical fertilizer (18-5-15-6-0,2), and 3) amended with compost prepared from oil-palm empty fruit bunches. Treatment four was the other control (soil from an area with low PC so far). A sample from all treatments was collected at 2, 4 and 6 months in 1999 to observe and measure root growth.

A gradual increase in root mass was observed throughout the experiment. A higher increase in root dry weight was observed in soil from site one amended with compost, except for the second sampling. The amount of large roots (primary and secondary) within the bags did not follow any particular pattern in time that could be associated with the treatments, but to normal seasonal variation caused by factors such as rainfall pattern. Growth of the fine root system (tertiary and quaternary roots), however, increased steadily through time in all treatments. Soil from site one amended with chemical fertilizer promoted root growth initially but this effect was of short duration and root mass soon returned to what was probably the normal levels sustained by this particular substrate. On the other side, the effect of the organic amendment had a longer effect on root mass due in part to the slow nutrient-releasing properties of organic matter.

Differences in root mass, though evident, were not statistically significant due to the high data variability (large differences between plants). This is a normal behavior of the root system, where variability can be higher than 20%. However, the use of each plant as a block or replication helped to reduce such variability. Complementarily, a regression analysis was run between root weight and length, where the lineal model had a R^2 of 0.76 for samples where weight was between 0 and 7 grams. This model allows estimating an *srl* (specific root length) value from the weight of a root sample facilitating analysis and data interpretation.

Introduction

Research on the dynamics of the root system of the oil pal is scarce and most studies focused on the effect of some agronomic practices and root distribution in soil (Forde 1972, Tinker 1976, Tan 1979, Agamuthu and Broughton 1986, Goh and Samsudin 1993, Jourdan and Rey 1997).

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Some of these studies have shown a positive effect of irrigation, a balanced nutrition and tillage that promoted soil aeration. The beneficial effect of these practices on root formation and health were more evident if they were done during the first five years after planting.

The main phytosanitary problem of the oil palm in many plantations in tropical America is the so-called spear and bud rots, being the 'pudrición del cogollo' or PC the most mentioned in the literature. In Costa Rica, a similar disorder is known as 'flecha seca' (dry spear) where most plants recover from symptoms after a variable period. These disorders are associated with the health of the root system (Chinchilla and Durán 1998, Albertazzi et al. 2005).

PC and related disorders may be in part the result of accumulated stress on the plant, where symptoms appear after a triggering factor such as a severe drought or prolonged soil saturation, normally associated with a previous heavy load of bunches in the plants. These and other factors cause severe root damage and a final break-down of the plants, where numerous opportunistic pathogens cause further damage (Chinchilla and Durán 1998).

In this work we studied the dynamic of the root system of young oil palms as affected by soil obtained from areas where PC-like symptoms were prevalent and we amended them with organic and chemical fertilizers.

Materials and methods

The experiment was conducted during the first semester of 1999 using 14 months old oil palms (variety Deli/Yangambi x Ekona), that had been planted in a commercial plantation located on the central Pacific coast of Costa Rica. The previous oil palm plantation had been affected by a PC-like disorder, known locally as 'flecha seca' (dry spear), which is of non-lethal character. The area is mostly flat, with soils of alluvial origin classified mainly as Inceptisols (Pérez et al. 1978).

The in-growth method described by Bhöm (1979) was used to monitor root development. Bags of a slow-degrading material (12 liter capacity, doubled bags of fiberglass) were filled with the corresponding substrate and buried 30 cm deep next to the plant. Each bag was marked accordingly.

Soils from two sites were used to fill the bags. Site one was an area where PC-like symptoms were prevalent, and site two was a place where the incidence of the disorder was very low at that moment. Soil from site one was amended with chemical fertilizer (treatment 2: 100 g of formula 18-5-15-6-0.2), or compost (treatment 3: 10% (w/w) of compost made from oil-palm empty fruit bunches. There were two controls of soils without amendments: soil from site one (treatment one) and site two (treatment 4). Each treatment had five replications.

The experiment comprised three groups of five plants each. The four treatments were applied to each plant by burying the bags at equidistant points from the palm stem. Each group of five plants was considered a complete randomized block design with five replications. Each palm was a block, and a total of 60 bags were used. Bags were collected at 2, 4 and 6 months from the time the experiment started.

Upon collecting the bags, roots growing outside the bags were cut off and the content of each bag was placed inside a 20-l plastic container to manually collect most of the roots. Then, the content was sieved through a 1 mm^2 mesh to recover the remaining roots. Large roots (primary and secondary) were separated manually from fine ones (tertiary and quaternary), following the guidelines in table one. Finally, the roots were placed in paper bags and put to dry in an oven (65°C during 48 hours) to determine their dry matter.

Table 1. Morphological characteristics of the root system of the oil palm[1]

Anatomical Classification	Typology	Diameter (mm)	Length (cm)	Longevity (months)	Branching
Primaries	horizontal	5	600	>6	+
	vertical	6.5	2500	1 - 6	+
Secundaries (II)	horizontal	2	200	1 - 6	+
	geotropism +	2.2	600	1 - 6	+
	geotropism -	1.5	50	1 - 6	+
Tertiaries (III)	superficial	1	20	<1	+
	deep	1	10	<1	+
Quaternaries (IV)	---	0.5	1.5	<1	-

[1] *Adapted from Jourdan and Rey 1997; (+) indicate that this type of root branches*

The program ROOTEDGE, version 2.2c (Kaspar and Ewing 1997) was used to analyze the scanned image of the roots to determine total length of the sample. The specific root length (*srl*) of the sample was determined from Bhöm's equation.

srl = total length of roots / dry matter of the sample

The *srl* value is normally expressed as millimeters in one gram of dried roots (Goh and Samsudin 1993). This value was transformed to log (*srl*) to conduct an ANDEVA, which considered the fact that palms were not assigned randomly to sampling dates, so these were considered as three separated experiments (three CRBD corresponding to the three sampling dates).

Treatment means were compared by contrasts: soil from site one (high incidence of PC) vs. soil from site two (low incidence of PC), soil amended with chemical fertilizer vs. the use of compost, and compost vs. no amendment. Tables 2 and 3 show results of the chemical analyses of the soils and compost used. Figure 1 shows the rainfall records during the period of the experiment.

Table 2. Chemical characteristics of soils and compost used to fill the in-growth bags

	pH	N	P	K	Ca	Mg	Al	Ac	CICE	S	Zn	B	Fe	Mn	Cu
		cmol$^{(+)}$/l								**mg/l**					
Reference	-	-	15	0.5	4	1	-	-	-	4	3	0.5	30	30	5
Soil 1	4.9	nd	0	0.2	16	2.7	0.9	0.9	20.3	8	3	1	164	113	17
Soil 2	6.8	nd	7.1	0.1	29	4	nd	0.1	33.3	nd	1	nd	46	3	5
		%								**mg/kg**					
Compost	nd	4.6	2.5	4.4	4.6	0.7	nd	nd	nd	nd	455	32	4126	184	39

Soils 1 and 2 obtained from sites with high and low PC incidence respectively. nd = not determined

Table 3. Base ratios in the soils used as substrate to fill the bags for root sampling

	Ca/Mg	Ca/K	Mg/K	Ca+Mg/K
Reference	2.5	5 - 25	2.5 - 15	10 - 40
Soil 1	6	80	14	30
Soil 2	7	323	45	74

Soil 1 and 2 came from sites with high and low PC incidence, respectively

Results and discussion

The observations on root development were started during a low rainfall period and ended once rains had already become established (Fig. 1).

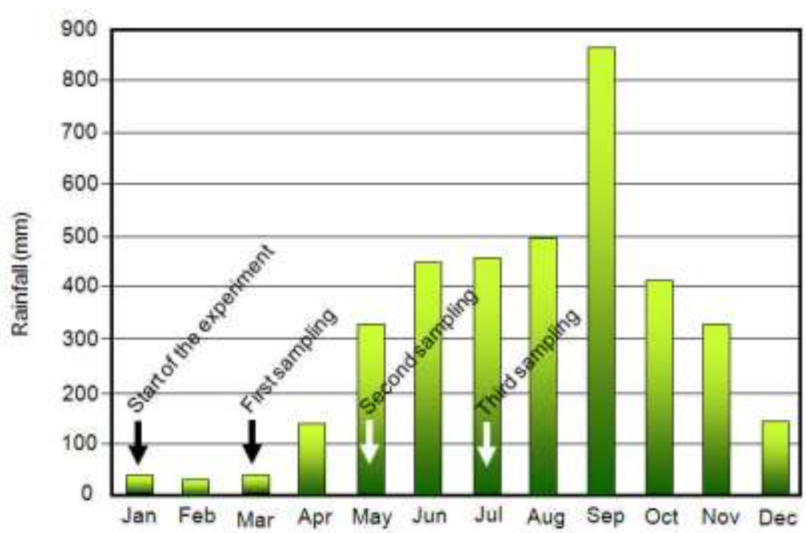

Fig. 1. Monthly rainfall (mm) during the year 1999. Quepos, Costa Rica. Arrows indicate dates for the start of the experiment and sampling dates.

Total root mass tended to increased steadily during the period of observation, except in the soil obtained from the area with low PC incidence, where root mass decreased during the second sampling. The highest rate of increase in dry root mass was observed in the soil amended with compost (Fig. 2C), but differences were not statistically significant.

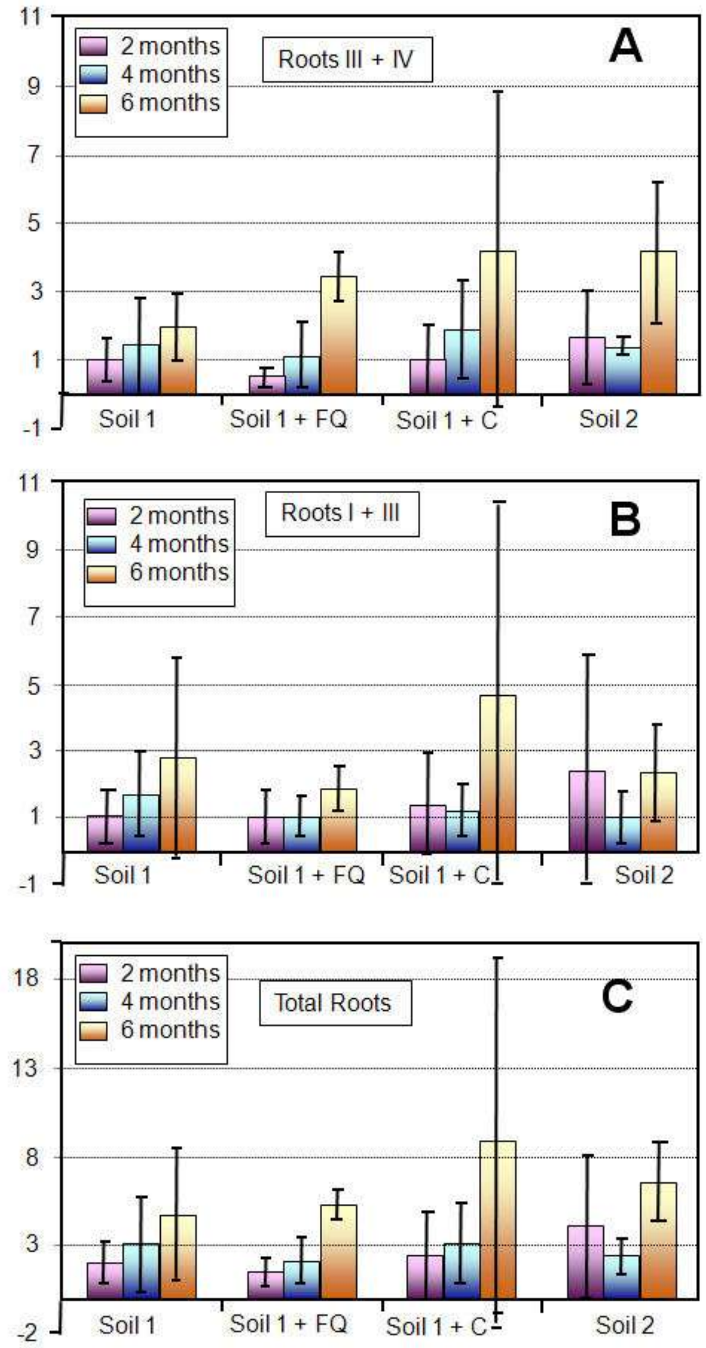

Fig. 2. Dry matter (g) of large (A: primary and secondary), fine (B: tertiary and quaternary) and total roots that grew inside bags filled with soil from two sites (high and low incidence of PC). Soil from site one was amended with compost (C) or chemical fertilizer (FQ). Root sampled at 2, 4 and 6 months. Palms were 14 months old in the field.

Changes over time in the amount of primary and secondary roots showed an erratic behavior (Fig. 2A). These large roots only increased steadily in the un-amended soil from site one. For all other treatment, root mass decreased during the second sampling. During the third sampling, root increment was particularly notorious in soil amended with compost. The erratic behavior in the amount of larger roots (primary and secondary) could be the result of seasonal variation in rainfall, and not a treatment response (Hartley 1977, Ruer 1967, Alvarado and Sterling 1993).

The behavior of the fine root system (tertiary and quaternary roots) was more constant (Fig. 2B) and the amount of roots tended to increase with time, but there were no significant differences between treatments. The highest increment was observed during the sampling done at six months in soil (from an area high in PC) amended with compost, followed by the soil from the area with low incidence of PC. In general, the soil amended with the chemical fertilizer presented the lowest values in root content (dry matter).

It was apparent that amending the soil with a chemical fertilizer initially caused an increase in the amount of fine roots (higher *srl*), but this effect did not last long (Fig. 3). The *srl* value was similar in the rest of treatments. At the end of the experiment (six months), the highest *srl* was observed in soil from site one without amendment.

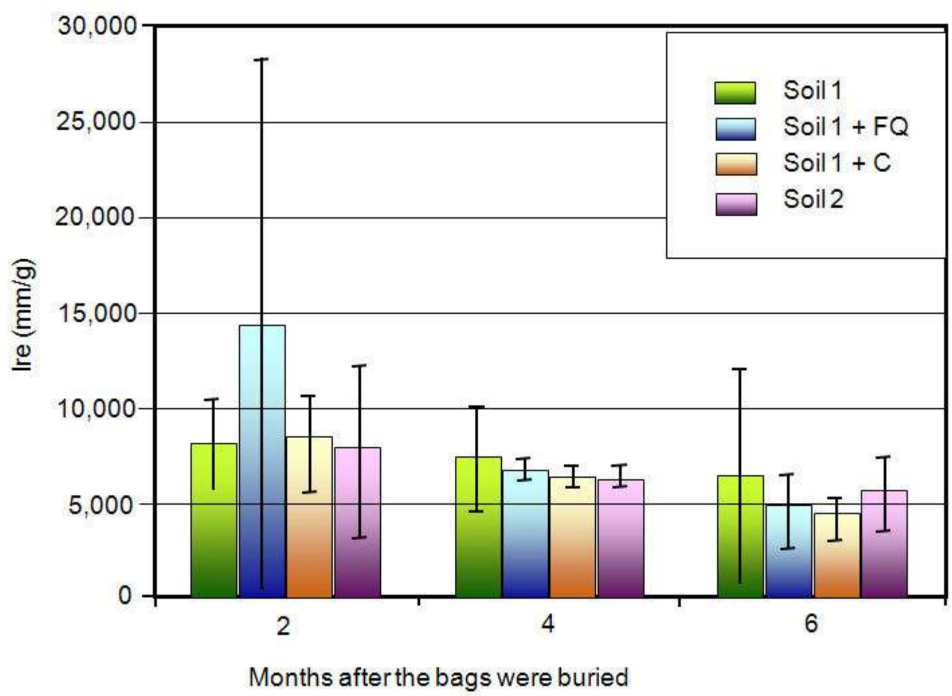

Fig. 3. Specific root length (*srl*: mm/g) within bags with soils from two sites (high and low PC incidence). The first soil was amended with compost (C) or chemical fertilizer (FQ). A sample of bags was taken at 2, 4 and 6 months. Palms were 14 months old in the field.

The short stimulatory effect of the chemical fertilizer on the root mass seems to be a natural response, since the plant would not invest energy unnecessarily to form excess of roots where nutrients are concentrated (Van Noordwijk et al. 1996, Arnone 1997, Charlton 1997).

The fine root system of the oil palm may show an 'instantaneous' response (patchy growth) growing toward a volume of soil where nutrients are concentrated (Jourdan and Rey 1997). However, if the resource is rapidly depleted, root longevity could be short under these circumstances, and more energy has to be invested to form more roots to explore new sites. Quaternary roots may have a medium life of 3-4 weeks and detach from tertiary roots about a month after they die. This implies that two months between observations (as used in this study) can be too long a period to observe the short effect of a particular treatment on quaternary roots.

On the other hand, the effect of compost was long lasting, which indicates a slow nutrient release effect keeping a stimulatory effect on root formation and survival (Grime et al. 1991). The effect was still observed during the last sampling (6 months after starting the experiment); at that moment, *srl* value was approximately 35% of that obtained during the first observation (Fig. 4).

Differences in root mass between treatments were large but statistically not significant since differences between plants were also large, which is common for this variable where it is normal to find variability larger than 20%. However, the use of single plants as replications helped to reduce such variability.

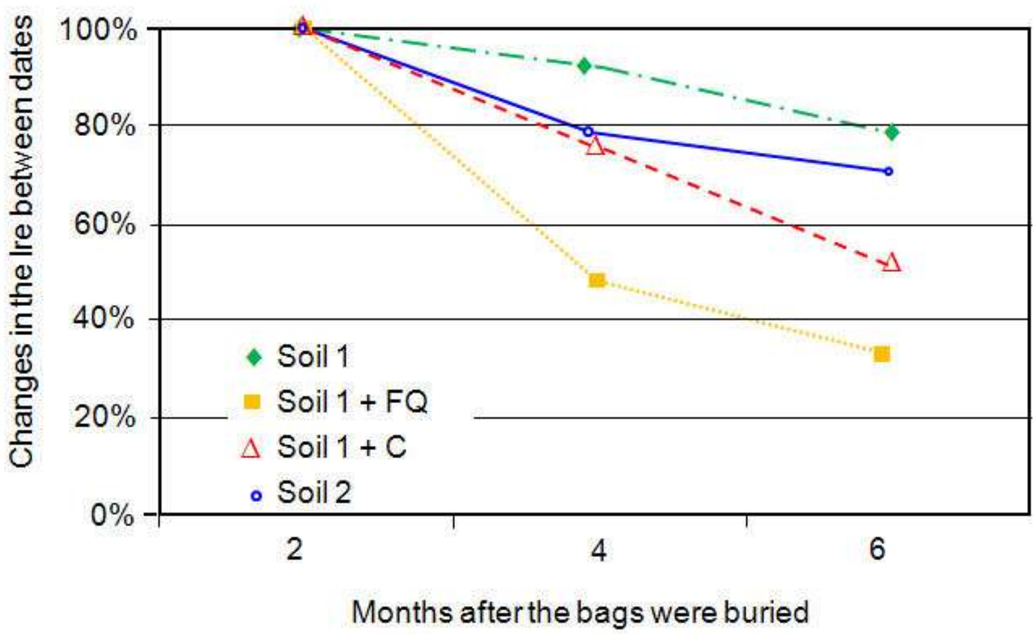

Fig. 4. Changes in *srl* between sampling dates (2, 4 and 6 months after placing treatments). Soils from two sites (high and low PC incidence). The first soil was amended with compost (C) or chemical fertilizer (FQ). Treatments were placed in bags buried near 14-months old palms.

A linear model ($R^2 = 0.76$, $P < 0.01$) was found when a regression analysis was run between fine roots (tertiary and quaternary) dry weight (between 0 and 7 g) and total root length (mm) of the sample (Fig. 5).

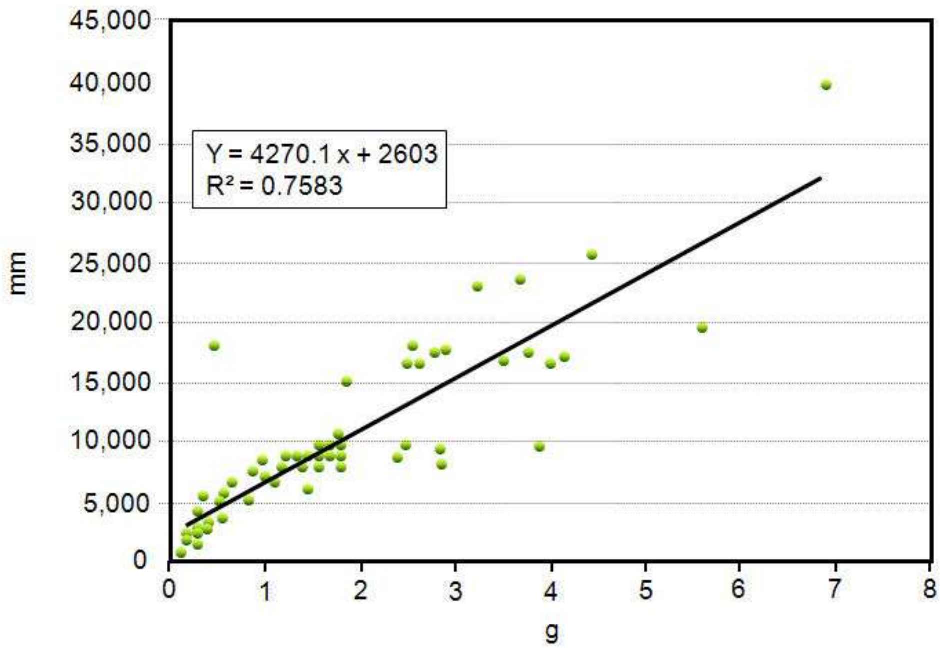

Fig. 5. Correlation between fine root (tertiary and quaternary) dry matter and total root length. All treatment and dates of samplings pooled.

Conclusions

The plant invests large amounts of energy to produce and maintain a healthy root system, and some events such as severe drought or prolonged water saturation cause large portions of the roots to die that must then be regenerated when water becomes available again or soil aeration is improved. Similarly, a plant may be stimulated to produce new roots to exploit a temporary source of nutrients, and this process demands energy that could be used for other processes. When a chemical fertilizer was used a temporary increase in root mass was observed, but this effect did not last long. The contrary was observed when the soil was amended with compost, where the roots apparently had greater longevity.

The results indicated that a soil sample obtained from a site were PC was prevalent did not have any particular characteristic that could not be improved through agronomy at that moment (increasing nutrient availability for example) in order to create a better environment for the growth of the root system, and at the same time reduce incidence and severity of the disorder.

A regression model permitted relating the dry matter of fine roots with their length. Such models allow estimation of the *srl* value from the data on root weight of fine roots, saving time and the need for special equipment and labor.

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