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Symptoms associated with water defficit in oil palm

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Introduction

Oil palm has long since been known as a crop with considerable water demands, and it generally develops in regions with precipitation levels above 2,000 mm and lacking prolonged droughts. A water supply of at least 150 mm/month is necessary for an optimum yield and performance (Hemptinne & Ferwerda, 1961). This is a condition which is seldom met, and it is frequent to find plantations where the water supply becomes critical several months in a particular year. In Costa Rica plantations, an accumulated water deficit is normally found only during the dry season, in the Pacific Central region (Quepos-Parrita), with an average deficit of 269.8 mm. (standard deviation: 105.5 mm), according to data recorded over a 9 year period (D.L. Richardson, personal communication). The purpose of this description is to guide the reader to the recognition of several symptoms associated with water deficit in plants of different ages.

Plants ten years old and up

In some areas of Quepos, it is common that plants suffer water deficit each year, and it is frequent to observe a premature folding over of the intermediate and inferior leaves, while they are still green (Fig. 1F). Very similar symptoms were described by Willard, Daniel & Ochs (1974) for even more severe drought conditions in West Africa. Some plants presented bent leaves as young as number nine, even though it was more frequent to find older leaves affected, up to position number 16. Premature leaf folding made its appearance associated with the accumulation of unexpanded new leaves (spears) in the plant (Fig. 1E). The most affected areas have soils and/or topography that favor water deficit, a condition that may lead to an earlier manifestation of the symptoms in these areas.

Once the older leaves were folded, they maintained their stomata closed during most part of the day, except for a few hours early in the morning. The reduced photosynthetic activity of these leaves, and their inability to translocate nutrients efficiently to the rest of the plant (due to the mechanical damage to the petiole), will possibly render them useless to the plant.

The magnitude of this reduction in leaf area was in direct relation with the intensity of the stress; some evidence (Villalobos, et al. 1990) indicates that the folding of those leaves probably responds in part, to a need to reduce the transpiration surface, and to help the young leaves maintain their water balance.

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Two years old and younger plants

The symptoms here described were observed in an area in Quepos, where because of differences in the soil water holding capacity, the sub-irrigation method in use presented variable efficiency levels. This condition, in conjunction with a severe dry season (Table 1), made it possible to observe plants with varying degrees of water deficit (Fig. 1B).

Table 1. Rainfall (mm) and estimated water deficit (mm) in three areas of Costa Rica during the 1989 dry season

Site	Dec-88	Jan-89	Feb-89	Mar-89	Apr-89	Deficit, mm	Water holding capacity, mm
Palo Seco, Quepos	55.0	2.0	0.0	0.1	47.3	436.5	225
Capital, Quepos	142.8	15.0	0.0	4.1	65.1	427.9	150
Coto 49, Coto	199.0	28.0	0.0	133.0	93.0	298.2	100

In very young plants (1-2 years old), the most evident symptom of water deficit was the accumulation of spear leaves (Fig. 1A). With the progression of the dry season, these plants presented an inward curling of the leaflets (rolling), and later necrosis of leaves, beginning on the tips of the leaflets of lower leaves (Fig. 1A & Fig.1B). In extreme cases, the necrosis of tissues extended to younger leaves with no previous chlorosis of the laminae.

Under extreme water deficit conditions, root necrosis of every order could be observed, and occasionally, the dead of a few plants. However, some badly affected plants reinitiated growth at the beginning of the rainy season. Young plants responded quite different from adult palms. The latter, because their large stem and extensive root system are able to buffer some of the negative effects of the water deficit.

Four year old plants

Coto, a region in Southern Costa Rica, does not normally present water deficit. Nevertheless, the 1989 dry season (Table 1) was rather severe in this region, and symptoms of water shortage were observed in some areas. Four year old plants grown in a soil with a reduced capacity to retain moisture, with a superior horizon 7-10 cm deep, followed by a layer of accumulated gravel of variable depths, began to develop severe deficit symptoms. Partly due to the aforementioned characteristics of the soil, the observed symptoms were the result of a combination of a deficient water supply and nutritional deficiencies, mainly nitrogen and magnesium (Fig. 1C). The vegetative growth of these plants was markedly reduced for their age; the variables in Table 2 show a reduced accumulation of dry vegetative matter and a poor vegetative development, when compared to plants of the same age and material growing under more normal conditions.

In March, the plant presented several spears, besides yellowing and/or bronzing starting at the tips of intermediate and inferior leaves. Initially, the leaflets tissue necrosed between the veins, and a overall desiccation of the whole leaf followed (Fig. 1C & Fig. 1E). In some cases, the yellowing was more accentuated on one side of the leaf. The bunches already formed were small, and fruit ripening was delayed. Bunch failure was common.

In spite of their reduced length and weight (Table 2), some intermediate and inferior leaves were broken at the rachis, approximately at one third from the leaf base (Fig. 1D). This phenomenon may be considered analogous to the premature folding of the green lower leaves in adult palms under stress. Nevertheless, it was obvious, in this case, that this was not a mechanism to reduce moisture deficit effects within the plant, but a consequence of very severe stress conditions.

Table 2. Morphometric variables of two groups of four years old palm (Deli x AVROS) growing under different water deficit conditions

Water deficit	Trunk height	Trunk dry weight	Petiole length	Rachis length	Frond number	Leaf dry weight	VDM (Kg)^2	Leaf area(m^2)	Total leaves	Spears
	0.155	3.05	0.81	2.87	30	1.4	45.0	5.7	171.9	4
	0.055	0.95	0.98	3.04	28	1.0	28.9	4.9	137.8	3
Deficit	0.105	2.20	1.08	3.12	36	1.1	41.7	5.5	199.8	4
	0.140	2.30	0.85	3.38	27	1.3	37.4	7.5	201.7	3
	0.085	1.20	0.89	3.49	22	1.2	27.6	4.6	102.3	4
	0.130	0.05	0.87	2.89	25	1.4	35.0	7.0	174.0	4
Average	0.12	1.60	0.92	3.13	28	1.3	36.0	5.9	164.6	4
	0.80	16.00	1.30	4.69	38	2.0	93.1	6.3	238.0	1
Normal	0.72	20.10	1.45	4.76	40	2.1	105.0	7.2	288.6	1
	0.68	16.90	1.21	4.20	43	1.7	88.4	5.2	224.4	1
	0.50	19.80	1.37	4.68	43	2.2	113.1	6.4	275.0	1
Average	0.63	18.20	1.33	4.58	41	2.0	99.9	6.3	256.5	1

Variables determined according to Corley & Breure, 1981.

An excellent indicator of water availability in the soil was the appearance of the cover crop (*Pueraria phaseoloides*), in which the symptoms of water stress first showed up; the foliage dried up, leaving only a few small yellowish leaves, giving the appearance of being intoxicated by a contact herbicide (Fig. 1A-1F).

Fig 1A. Symptoms associated with water deficit in 10 month old plants in the field.

Fig 1B. Symptoms associated with water deficit in 10 month old plants in the field

Fig 1C. Symptoms associated with water deficit in four month old plants in the field.

Fig 1D. Symptoms associated with water deficit in four year old plants in the field.

Fig 1E. Symptoms associated with water deficit in four year old plants in the field.

Fig 1F. Symptoms associated with water deficit in 22 year old plants in the field.

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Variation in the total of unsaturated fatty acids in oil extracted from different oil palm germplasm

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Introduction

A higher unsaturated-fatty acid content in palm oil is considered of primary importance in oil palm breeding (Arasu et al. 1987). Unsaturation of the fatty acids is defined as the proportion and position of the double bonds in the hydrocarbon chain of the fatty acids (Hartley 1977).

Hardon (1969) demonstrated that there are significant differences between the species *Elaeis oleifera* and *Elaeis guineensis* regarding the content and type of fatty acids present in their oils. The oil of *E. oleifera* presents the lowest saturation; in the case of the interspecific hybrid of *E. oleifera* x *E. guineensis* (OxG) intermediate values are normally found; and *E. guineensis* presents the highest degree of saturation. Eventhough *E. oleifera* is not cultivated on a commercial scale due to its low oil extraction rate, Ooi, quoted by Rajanaidu et al. (1983) found a biotype of this specie in Brazil with high oil percentage in the bunch.

Wuidart & Gascon (1975), Noiret & Wuidart (1976) and Ng et al. (1976) found that the oil from palms of La Mé origin has unsaturation percentages of 55%, while Deli and Yangambi have less than 51% and 50.4% respectively. Besides the comparison in the behavior of their descendants, it was observed that the Yangambi origin reduced the quantity of unsaturated fatty acids. Furthermore, fruit with *pisifera*-type have greater amounts of linoleic acid (18:2) and less palmitic acid (16:0), in their oil, than the *dura* and *tenera* types (Ng et al. (1976).

For the reasons mentioned above, hybridation pretends to improve oil quality in *E. guineensis*. In this study, the variation found in the saturation percentage of the fatty acids in germplasm belonging to the Chiquita International Breeding Program (Palm Research Program) will be discussed.

Materials and method

In order to determine the characteristics of the different oils that are being studied, sampling methods which permit an adequate extraction and conservation of each type of oil have been developed (Wuidart & Gascon, 1975; Rajanaidu & Tan, 1983).

The sampling for this research was performed during 1988 in 37 oil palm progenies, at the experimental station in Coto, Costa Rica. From each one of the progenies selected, at least four plants were sampled and from each plant an average of 6 subsamples were obtained throughout the sampling period. One hundred and seventy-six individual palms of Compact material were studied (Sterling et al. 1988), plus hybrid OxG, *E. oleifera* and *E. guineensis* palms.

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From each bunch, subsamples of 100 g of mesocarp were collected and sterilized at a pressure of 1.0 kg/cm² for 15 minutes and desiccated at 105°C for three hours. The oil was extracted with 150 ml of petroleum ether and then vacuum-filtrated through N1 Watman paper. The ether was separated by distillation at 65°C. Before storing at -10°C, a small amount of sodium sulphate was added as a dehydrating agent. At the end of the sampling period, the subsamples were homogenized by fusion of the oil at 65-70°C.

The iodine value (IV) was determined by the Wijs method (AOCS, 1973); the 50 samples with the highest unsaturated fatty acid content were sent to the Institut de Recherches pour les huiles et Oleagineux (IRHO Montpellier, France) in order to determine their chemical composition by gas chromatography.

Result and discussion

Table 1 shows the average results of IV obtained from the evaluated crosses. It is interesting to point out the closed relation found between the magnitude of the IV and the origin of the genetic material. The IV's above 60% correspond to *E. oleifera* and the values nearest 50% to *E. guineensis* material. Intermediate values between 50-59% were almost totally obtained from interspecific hybrids, Compacts and backcrosses of *E. guineensis* and Compacts.

Wuidart & Gascon 1975, Noiret & Wuidart 1976, affirm that the main source of high levels of unsaturated fatty acids (60 to 75%) in the oil palm industry, is the germplasm of *E. oleifera*, this findings were in agreement with the results presented in Table 2 .

The Compact material obtained by the Palm Research Program (PRP) is being developed by recombinations of *E. guineensis* and interspecific hybrids (Sterling et al, 1988), which shows a greater proportion of unsaturated fatty acids. In Table 3, a direct relation between the total of unsaturated fatty acids and the iodine value is evident, regardless of the genetic origin of the oil palm material.

It is interesting to note the behavior of the CAM 240 and CAM 236 accessions, which present a high percentage of oleic acid (18:1), superior to the value observed in Deli x AVROS and Compacts. Self-pollinated Compact and Pobè materials exhibit a greater proportion of saturated fats (16:0 and 18:0) and therefore a lower Ioidine value.

In the correlation analysis between the percentage of the different fatty acids present in the oil and the Iodine Value, a significant and positive relation was found between myristic (14:0) and palmitic (16:0) acids, as well as between the unsaturated oleic (18:1) and linolenic (18:3) acids (Table 4). The Iodine value also presents a high positive correlation with the oleic acid (18:1), while its behavior is inverted in relation with the palmitic acid (16:0) (Table 4).

Table 1. Average iodine values (IV) for different *E. oleifera*, *E. guineensis* and OxG progenies

Progeny	Origin	n	IV AVG	Std. Dev.	Variation	
					Min.	**Max.**
C2513	E.o.xE.o.	5	79.02	5.96	68.80	84.00
C2530	E.o.xE.o.	5	80.80	4.38	76.00	84.00
C9153	E.o.xE.g.	5	63.20	3.35	60.00	68.00
C9173	E.o.xE.g	4	63.10	4.78	59.20	70.00
C9177	E.o.xOCP	5	67.04	4.21	60.00	71.00
C9186	E.o.xOCP	3	65.87	5.62	60.00	71.20
C1780	OCPself	2	45.00	1.41	44.00	46.00
C1918	OCPxE.g.	6	46.10	5.17	38.80	53.00
C415	OCPxE.g.	5	49.60	2.96	44.60	52.40
C9086	E.g.	5	49.52	3.69	46.00	54.80
C9124	OCPxE.g.	5	48.56	1.82	46.80	50.80
C9171	E.g.	4	46.30	4.36	40.00	50.00
C1829	OCPxE.g.	3	59.00	1.41	44.00	46.00
C1846	OCPxE.g.	3	52.93	2.01	50.80	54.80
C1879	OCPxE.g.	4	53.40	3.62	50.00	57.20
C1886	OCPxE.g.	3	51.33	3.95	46.80	54.00
C1986	OCPxE.g.	4	53.60	3.23	49.20	56.40
C265	OCPxE.g.	6	58.53	4.21	53.20	64.80
C288	OCPxE.g.	4	54.00	3.13	50.80	58.00
C333	OCPxE.g.	3	51.87	0.46	51.60	52.40
C3671	E.g.	10	52.42	2.43	46.80	54.80
C382	OCPxE.g.	2	55.20	3.96	52.40	58.00
C9076	OCPxE.g.	4	54.00	5.05	50.00	62.80
C9101	OCPxE.g.	4	52.60	6.96	45.20	62.00
C9117	E.g.	5	52.24	6.21	46.00	60.40
C9122	OCPxE.g.	4	52.60	2.80	49.20	55.60
C9123	OCPxE.g.	3	54.80	0.80	54.00	55.60
C9129	OCPxE.g.	5	52.32	6.25	42.80	60.00
C9130	OCPxE.g.	5	53.44	3.09	48.00	55.60
C9143	OCPxE.g.	5	56.56	3.85	51.60	62.00
C9245	OCPxE.g.	4	55.60	2.85	51.60	58.00
C9248	OCPxE.g.	8	56.40	3.45	52.40	62.80
CAM236	E.g.	4	58.80	1.47	58.00	61.00
CAM240	E.g.	4	58.60	2.39	56.40	62.00
GHA648	E.g.	4	53.40	1.51	52.40	55.60
TAN544	E.g.	4	54.20	3.29	50.00	58.00
C1879	OCPxE.g.	4	63.20	-------	63.20	63.20

OCP = Compact, CAM = EKONA, GHA= Calabar, TAN = Kigoma

Table 2. Iodine values (IV) in oils of different origins, from the germplasm bank in PRP, Coto

Material (1,2)	**n**	**AVG**	**C.V.**	**Min.**	**Max.**
E.o.xE.o.	10	80.0	6.4	68.8	84.0
E.o.xOCP	8	66.4	7.4	60.0	71.0
E.g.xE.o. F1	9	63.1	5.3	59.2	70.0
(OCPxE.g.) xE.g	12	57.0	5.2	51.6	62.8
OCPxE.g.	78	53.5	5.6	38.8	64.8
DelixAVROS	20	51.4	7.8	40.0	54.8
TAN544	4	54.2	6.0	50.0	58.0
CAM240	4	58.6	4.1	56.4	62.0
CAM236	4	58.0	2.5	58.0	61.0
GHA648	4	53.4	2.8	52.4	55.6
OCP Self.	2	45.0	3.1	44.0	46.0
Pobè	4	46.3	8.2	40.0	50.0

Table 3. Variation in the chemical composition of fatty acids from different oil palm materials; percentages of the fatty acid composition totals determined by gas chomatography

Material	n	Palmitic 16:0*	Stearic 18:0*	Oleic 18:1*	Linoleic 18:3*	Unsaturation Total	IV
E.o.xE.o.	3	21.1	1.4	59.4	16.6	77.4	84.0
E.o.xOCP	2	33.9	1.8	40.9	13.2	63.8	71.2
E.o.xE.g.	3	32.9	2.0	50.0	13.6	64.1	67.3
(OCPxE.g.)xE.g.	4	46.8	2.7	37.9	11.0	49.3	59.2
OCPxE.g.	25	43.8	3.7	40.8	10.7	51.9	59.3
Deli x AVROS	6	43.7	4.1	39.2	11.2	51.0	53.8
TAN 544	1	44.9	6.0	34.8	13.1	48.3	58.0
CAM 240	1	38.9	6.2	47.9	5.3	53.7	62.0
CAM 236	1	36.4	9.8	44.3	8.0	52.8	58.2
GHA 648	1	47.1	5.4	31.8	13.7	46.1	55.6
OCP SELF	1	49.1	3.3	35.7	9.5	45.8	46.0
Pobè	2	44.7	5.8	36.2	10.2	46.9	49.0

***Number of carbon molecules:number of double bonds.**

Table 4. Correlation Coeficients between percentages of different fatty acids and the Ioidine value in oil extracted from oil palm

	Satured				Unsatured				IV
	Myristic C14:0*	Palmitic C16:*	Stearic C18:0*	Arachidic C20:*	Palmitic C16:1*	Oleic C18:1*	Linol. C18:2*	Linolenic. C18:3*	
C14:0	1.000	0.718	0.098	0.374	-0.408	-0.753	-0.122	-0.159	-0.611
C16:0		1.000	0.222	0.409	-0.631	-0.933	-0.315	-0.465	-0.824
C18:0			1.000	0.560	-0.481	-0.236	-0.520	-0.287	-0.447
C20:0				1.000	0.499	-0.429	-0.249	-0.119	-0.562
C16:1					1.000	0.454	0.575	0.675	0.721
C18:1						1.000	0.536	0.287	0.749
C18:2							1.000	0.516	0.522
C18:3								1.000	0.557
IV									1.000

* Number of carbon molecules: number of double bonds.

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