Genetic variability of the root system of the oil palm under drought conditions. Consequences on root distribution, dynamics and water uptake.

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Drought effects on oil palm.

General objective The genetic variability of morphophysiologic characteristics of root system of oil palm was studied in Benin, western Africa, under drought conditions. The present study was focused on root distribution, root dynamics and water uptake of different oil palm genotypes known to have variable levels of tolerance to drought.

4-year-old oil palms in Obeke plantation, Benin

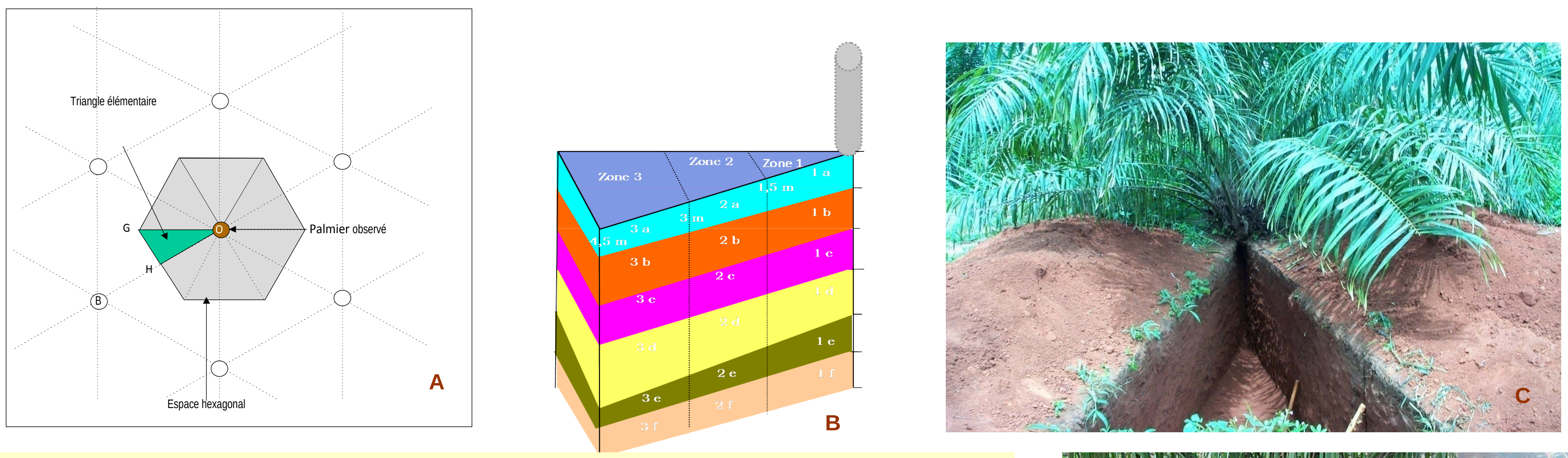

Fig. 1. Voronoï space defined by the half distance between the sampled tree and its neighbors (A). Observed elementary square triangle made of 3 zones and 6 soil layers (B) and photo in the field (C).

Material & Methods

The drought sensitive genotype was named E (C2001: (LM404DxDA10D)xLM2T);The drought tolerant was named C (C6446: DA8Dx(LM9TxLM13T)) whereas the labeled B (C1001F: DA115DxLM2T) genotype was intermediate. Studies were set up in the field at Obeke plantation (2°35' east, 6°55' north), on 3- to 5-year-old oil palms (Nodichao *et al.*, 2011). For root distribution study, the representative sample was defined by one elementary triangle of Voronoï space (Fig. 1A). In the triangular pit, 3 zones were defined according to the distance to the sampled tree (zone 1: 0-1.5m; zone 2: 1.5-3m; zone 3: 3-4.5m) and 6 soil layers were excavated up to 1.7m deep (Figs. 1B, 1C). Three replications on each genotype were realized. All types of roots were sorted out, washed and scanned for root length and surface estimation. Then, roots were dried (80°C, 48h) and weighted for biomass/necromass determination. Root image analysis was performed by "Winrhizo" software (Regent Instrument Inc.) (Nodichao *et al.*, 2008). For root dynamics study, 18 field rhizotrons (Fig. 2) have been set up on different genotypes. Root growth monitoring was carried out every weeks during 1 year. Root dynamics analysis was performed by RhizoDigit software (CIRAD©). The soil fraction explored by roots for water uptake (EX_θ) was estimated by the equation 1 according to Chopart (1999).The root uptake efficiency for water (EAH) was estimated by equation 2 derived from Proffit (1985) and Annerose (1990) results.

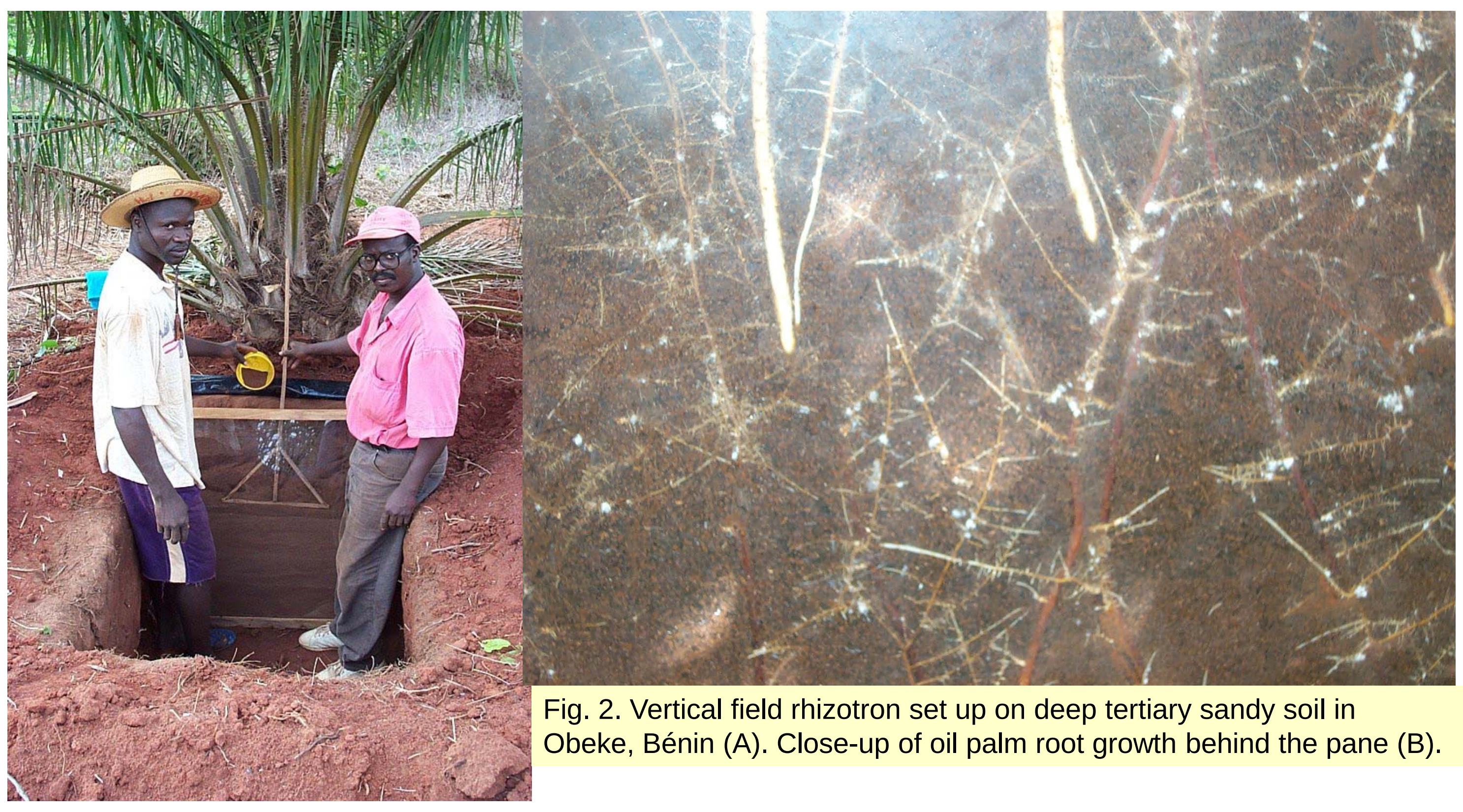

Fig. 2. Vertical field rhizotron set up on deep tertiary sandy soil in Obeke, Bénin (A). Close-up of oil palm root growth behind the pane (B).

Equation 1

If EMR/2 > r then, $EX_{H2O} = \frac{4}{3} * \left(\frac{r}{EMR}\right)^2$

If EMR/2 < r then, $EX_{H2O} = 1 - \frac{EMR}{3 * r}$

where r is the maximal distance from root for water uptake,
and EMR/2 the half distance between roots,
with EMR≈2*(π*RLD)-0.5 according to Newman (1966),
where RLD is the root length density (cm.cm-3).

Equation 2

$$EAH\,(mm^3 c^{-2} d^{-1}) = \frac{ETi * Si * 100}{SRi}$$

where ETi = root water uptake in soil layer "i" (mm.j-1),
Si = surface of the soil layer "i" (cm²),
Sri = Total root surface in soil layer "i" (cm²).

Tab. 1. Percentage of root length in the rooting zone (soil horizons and distance from palm tree) for the different oil palm genotypes, set up in a 4-year old plantation in Benin.

Rooting zone distance to tree (m)	Soil horizons (cm)	Genotypes		
		B	C	E
	0-20	10.94	9.20	13.61
Zone 1 (0 - 1.5m)	**20-50**	12.56	10.83	11.06
	50-170	11.31	10.55	9.69
	0-20	16.24	16.44	18.59
Zone 2 (1.5 - 3m)	**20-50**	12.74	12.35	11.37
	50-170	9.99	13.95	12.62
	0-20	11.66	10.27	10.38
Zone 3 (3 - 4.5m)	**20-50**	9.19	8.09	7.83
	50-170	5.37	8.32	4.85
		100	100	100

Tab. 2. Total root biomass, length and surface of different oil palm genotypes, set up in a 4-year old plantation in Benin.

Root parameters	Genotypes		
	B	C	E
Total root biomass (t.ha-1)	**2.87±0.17**	**3.22±0.25**	**2.41±0.30**
Total root length (km.ha-1)	**4061±132**	**4909±730**	**3131±686**
Total root surface (ha.ha-1)	**2.33±0.04**	**2.70±0.33**	**1.87±0.32**

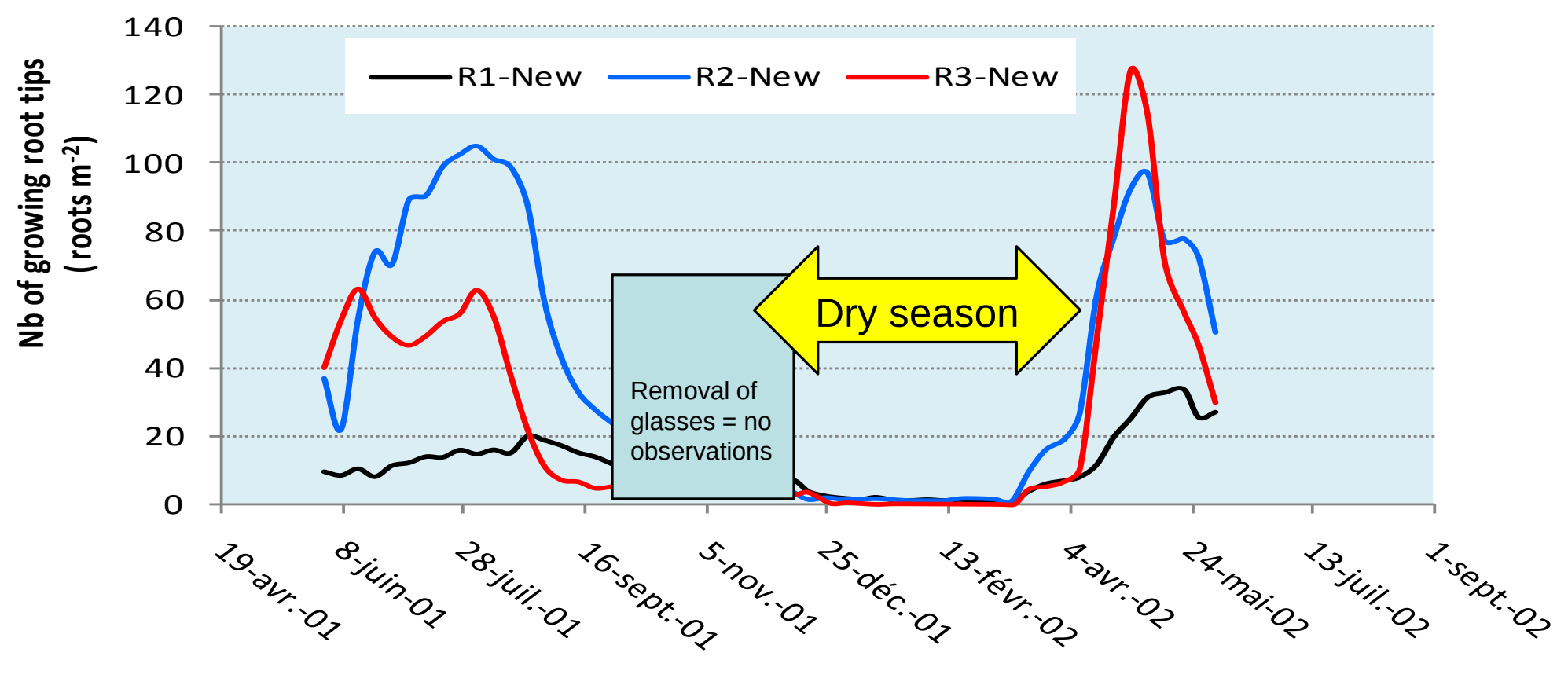

Fig. 3. Evolution of oil-palm root growth over 1-year in Benin. Coarse root (R1) growth was more steady along seasons than fine root (R2+R3) growth

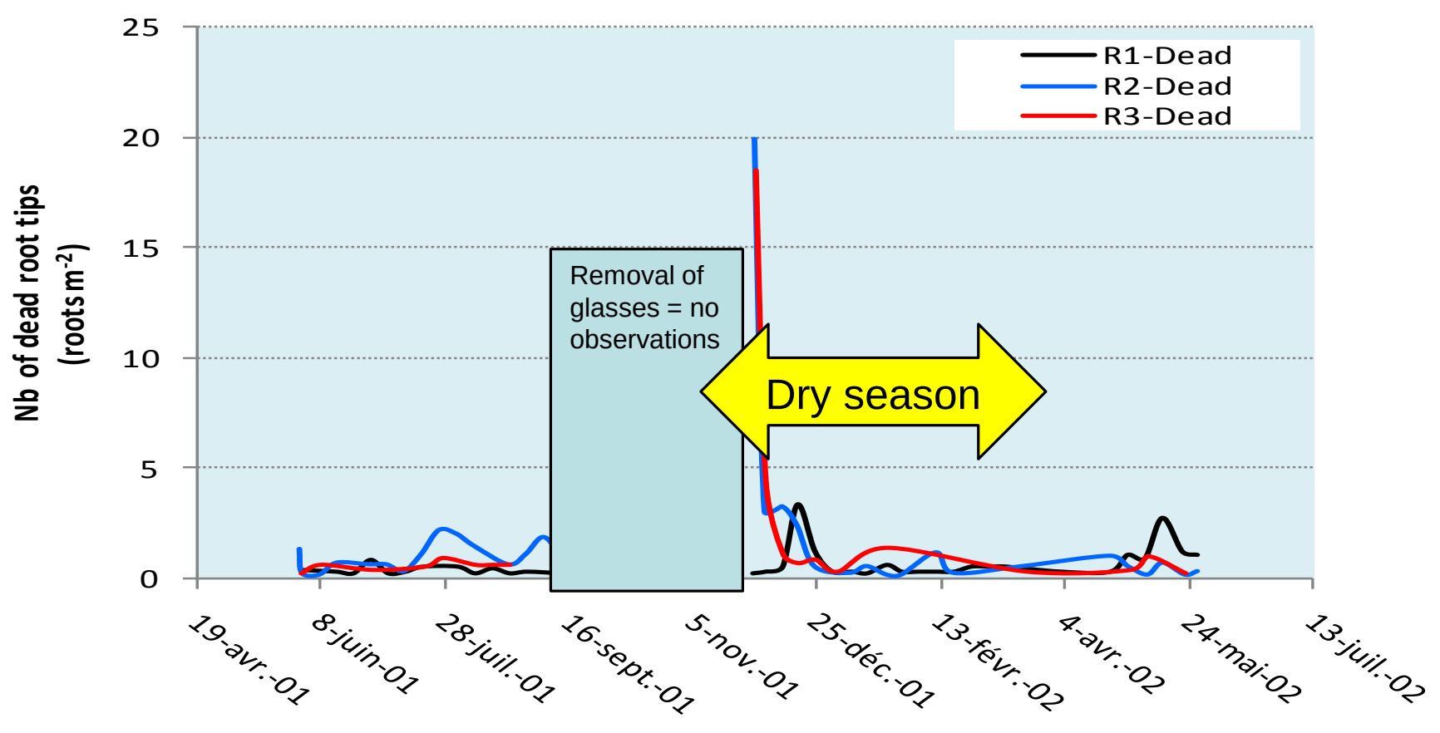

Fig. 4. Mortality of oil-palm roots along seasons in Benin affect more strongly the fine roots (R2+R3) than the coarse roots (R1).

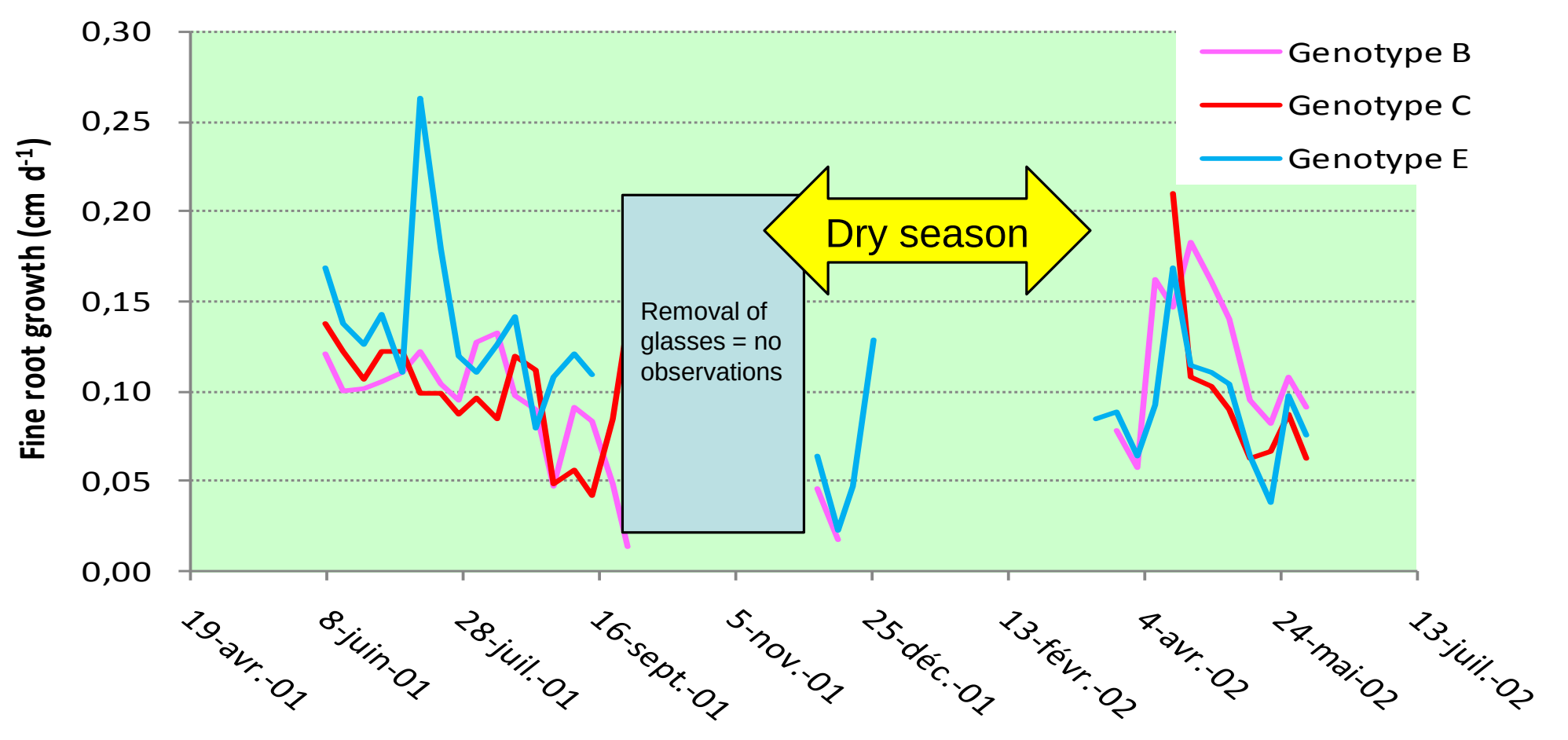

Fig. 5. Effect of dry season (no rain) on fine root dynamics of different oil palm genotypes in Benin

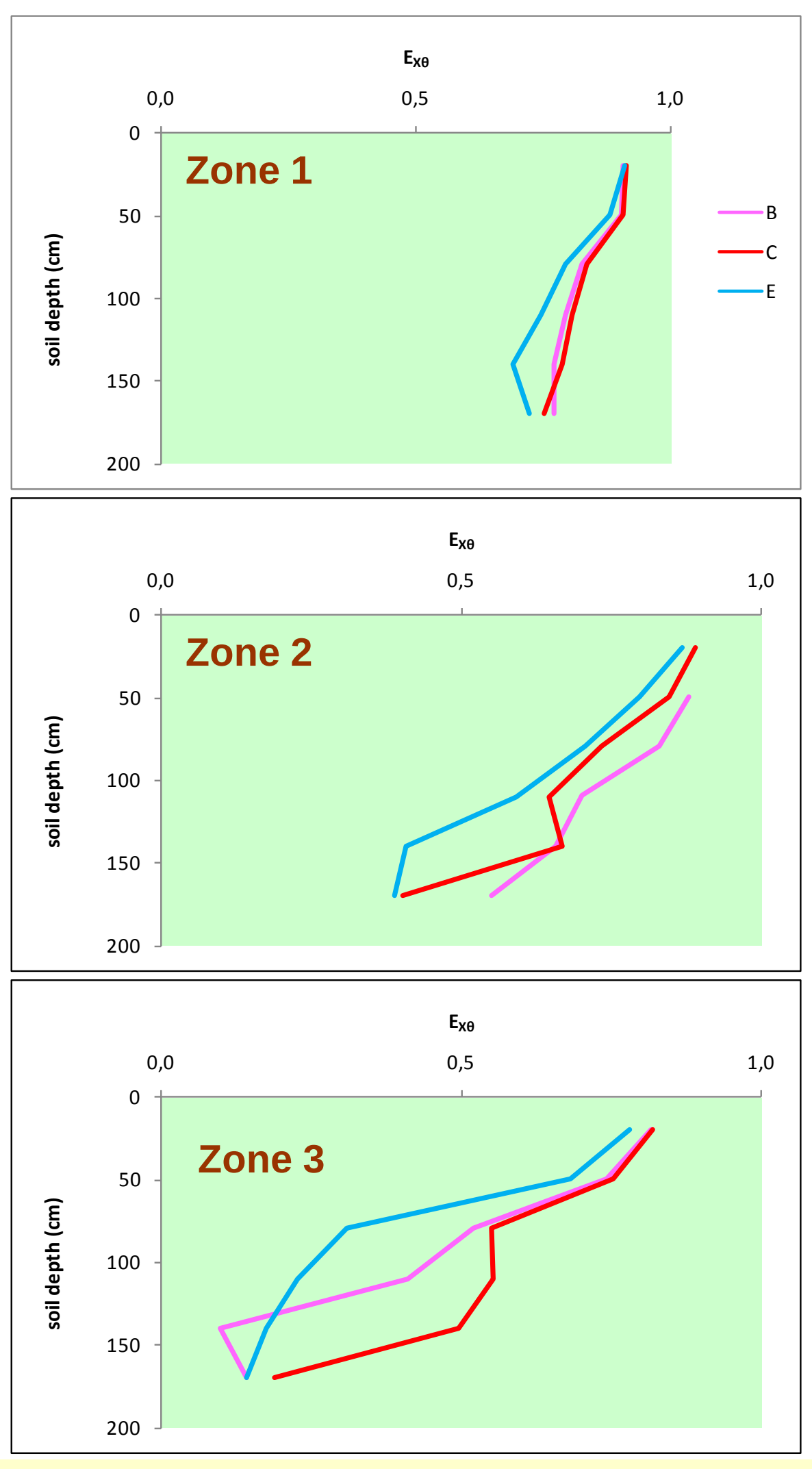

Fig. 6. Relationship between fraction of soil explored by roots for water uptake (EXH2O) and the rooting zone (depth and distance from palm tree) for the different oil palm genotypes

Results

Root system of the drought tolerant genotype (C) was less developed in the top soil horizon and near the palm tree than the other genotypes (Tab 1) but was more developed in the deeper horizons and far from the tree than others and particularly the sensitive one (E). Global root parameters (Tab 2) indicated that genotype C had more root biomass, length and surface than other genotypes. Root dynamics variations were greater within year than between years because of seasonal variations especially with the dry/wet cycle alternation (Figs 3,4,5). Root growth stop (Figs 3,5), even on drought tolerant genotype (Fig 5), and mortality increased significantly (Fig 4) as soon as dry period was established and root growth recovered as soon as significant rain occurred (Figs 3,5). No significant differences between genotypes were found concerning fine root dynamics (Fig 5). Fraction of soil explored by roots for water uptake (EX_θ) increased with root density. Differences between genotypes varied with soil depth and with distance from the tree (Fig 6). Differences between genotypes increased with soil depth particularly below 1 m deep where genotype C had still 50% of the soil volume explored by its roots whereas genotype E had less than 20%. Root efficiency for water uptake (EAH) varied with genotypes, the root growing depth, and the distance from the tree. EAH increased with depth and distance from the palm tree (Fig 7). Despite a more developed root system, the drought tolerant genotype (C) dried less the soil during the dry season than the supposed sensitive one (E) which had a high EAH particularly far from the tree (Fig 7).

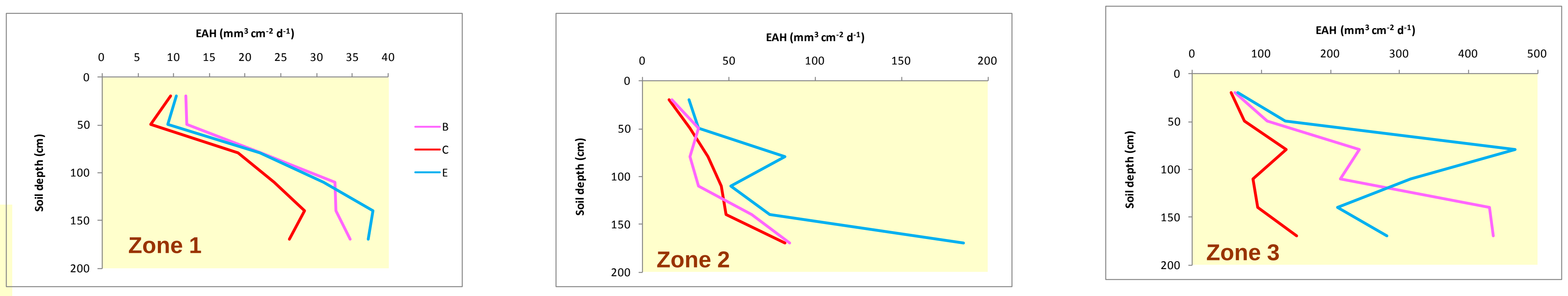

Fig. 7. Relationship between root efficiency for water uptake (EAH) of the different oil palm genotypes rooting depth and distance from the palm tree (zone 1: 0-1.5m; zone 2: 1.5-3m; zone 3: 3-4.5m).

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Conclusion

Drought tolerant genotype C was characterized by a better root development in deep horizons, minor in top soil, than sensitive genotypes. It dried less the soil, had a better stomatal conductance regulation and yielded more bunches (results not presented here) than others. Results allowed us to define an "idéotype" of oil palm for each drought intensity condition that could be found in marginal areas of oil palm plantations. In addition, practical strategies could be proposed to increase oil palm yield in marginal zone and orientate researches on oil palm adaptability to drought.

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