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New observations on the resistance of coconut cultivars to tropical cyclones in Vanuatu

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Abstract

The resistance of coconut palms to violent winds was observed at the Saraoutou research station as cyclone Dani passed over the island of Santo in Vanuatu in January 1999. Mortality caused by felling or uprooting was recorded on 13 Dwarf varieties, 10 Tall varieties and 28 Dwarf x Tall hybrids. The Dwarf palms were generally more susceptible than the Tall palms and hybrids, but substantial differences were also found between varieties in the same group. At 15 years old, the Tacunan Green Dwarf originating from the Philippines proved to be the most resistant Dwarf with 0% of felled palms compared to 100% of felled palms for the most susceptible, the Malayan Yellow Dwarf. Of the Tall palms, the Vanuatu Tall proved to be the most resistant with 2% of felled palms. The varieties originating from the South Pacific or the Philippines also displayed good resistance compared to varieties from Papua New Guinea. Of the hybrids, the Malayan Red Dwarf x Rennell Tall displayed the least resistance. The effect of different factors (morphological characteristics, age) on susceptibility to violent winds is discussed.

Key words: Pacific, Vanuatu, coconut, cyclone, genetic diversity, genebank.

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Introduction

In the Pacific Ocean, between the Solomon Islands and Fiji, the Vanuatu archipelago stretches over a distance of 850 kilometres between the 13th and 22nd parallels south of the equator. Vanuatu has an equatorial oceanic climate and is periodically subject to tropical cyclones. The Saraoutou coconut research station (now the Vanuatu Agricultural Research and Technical Centre) was founded in 1962 on the island of Espiritu Santo. Since that time, it has been particularly affected by cyclones Wendy in 1972, Gordon (1979), Nigel (1985), Dani and Ella (1999), and Paula and Sose (2001).

The initial work carried out at the station focused on coconut breeding. Thus, from its inception, collections containing varieties of different origins were planted, along with hybrid comparative trials (Calvez *et al.*, 1985; Labouisse *et al.*, 2004; Labouisse *et al.*, 2005). Through the genetic diversity of its collections and the large number of hybrids in trials, the centre is a unique site in the Pacific for observing how different coconut cultivars withstand tropical cyclones. An initial overview was conducted by Marty *et al.* (1986), but it only distinguished between groups of coconut palms (Dwarfs, Talls, hybrids) without going into detail about the performance of each variety.

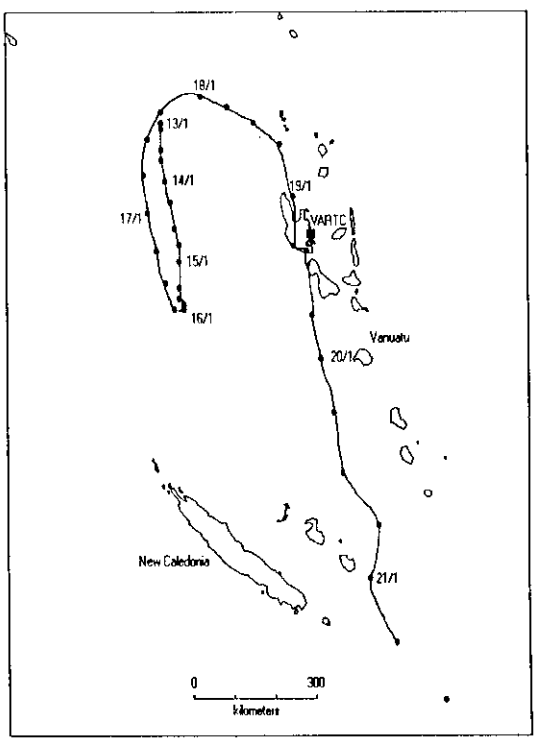
We present here observations carried out as tropical cyclone Dani passed over the island of Espiritu Santo from North to South, and struck the collections and trials at the station full on in January 1999. We indicate the differential susceptibility of the varieties and hybrids in relation to violent winds and propose some explanations.

Materials and methods

The Saraoutou station (longitude 167°12'E, latitude 15°27'S) is located 11 kilometres north of Luganville on the coast of Espiritu Santo. Its current domain extends over around 500 hectares, on a low terrace along the coast, comprising shallow humus-bearing coral soils, and a limestone plateau enriched with volcanic ash, with deep, fertile soils rich in clay (60-90%) and organic matter (Bonzon *et al.*, 1991). For this study, all the observations were carried out in coconut plots planted on the latter type of soil, varying in depth from 1.0 to 1.3 metres.

Observations were carried out after cyclone Dani passed through the island of Espiritu Santo from North to South following the 167th eastern meridian (figure 1). On 19 January 1999, the eye of the cyclone passed 30 kilometres to the west of the station with sustained winds reaching 100 knots, i.e. 185 kilometres an hour, with gusts of 120 knots, i.e. 222 kilometres an hour (Tomb, 1999).

Figure 1: Tracking map of cyclone Dani from 13 to 21 January 1999 (position measured every 6 hours)



The material observed consisted of Dwarf and Tall coconut palms of different origins (table 1), and of comparative trials of Dwarf x Tall hybrids set up under the regional PRAP programme (Pacific Regional Agricultural Programme) from 1982 onwards. The cultivars were in several plots spread over the station and planted at different ages. Exposure of the plots to violent winds generated by tropical cyclones varied depending on the environment (proximity to forest curtain or open pasture) and their aspect. We thus classed the plots according to 3 levels of exposure (low, moderate, high). Each plot was pedologically uniform, and contained coconut palms of the same age. Statistical designs had been set up in each plot to observe growth and yield traits, which facilitated a comparison between cultivars in those plots. Table 2 recaps the characteristics of the trials observed.

Results

Dwarf coconut palms

In plot (P31), which was highly exposed to gusts of wind, 51.8% of the 15-year-old Dwarf palms were felled. In all cases, they were snapped off at the root-soil plate level around ten centimetres below ground (figure 2). No stems had been broken above the ground and no palms had been totally uprooted. A small percentage of palms (4.7%) only had their stems left leaning by the wind after partial uprooting. Observations showed a wide range of susceptibilities between the Malayan Yellow Dwarf (MYD), the most susceptible with 100% of felled palms, and the Tacunan Green Dwarf (TACD), with no felled or even leaning palms (figure 3). The Vanuatu Red Dwarf (VRD) was also very resistant with only 3.8% of felled palms, as was the Samoan Yellow Dwarf (SYD) with 10.6%.

The same varieties were observed in another plot (P51), which was also highly exposed to wind, in 2 blocks planted 4 and 5 years respectively before the passage of the cyclone. In that plot, a majority of palms were left leaning and partially uprooted (19.2% for the 4-year-old palms and 46.1% for the 5-year-old palms), and a smaller proportion of totally felled palms (12.7% and 24.2% respectively). Figure 4 shows the percentage of felled and leaning palms depending on the variety in the block of 5-year-old palms. The Niu Leka Dwarf and Tacunan Green Dwarf varieties were the most resistant.

Tall coconut palms

The Tall coconut palms, which were between 11 and 16 years old and planted in 3 neighbouring plots, were clearly less affected than the Dwarf palms on the whole. Table 3 recaps deaths by felling, along with leaning palms, depending on the variety.

Coconut hybrids

Observations were carried out in 6 plots containing coconut palms aged 4 to 7 years when the cyclone occurred. In this case, various types of damage were seen with stems broken at different levels (figure 4). The numbers of felled and leaning palms were also recorded (table 4).

Discussion

Varietal susceptibility between and within groups

After the passage of cyclones Wendy in 1972 and Nigel in 1985, Marty (1986) carried out an inventory of damage seen on coconut palms at the Saraoutou station. He found 32.2% of Dwarf palms felled by Wendy and 57.2% by Nigel, as opposed to 5.6% and 10.4% respectively for the Tall palms, and 4.6% and 14.6% for the hybrids. The observations carried out after the passage of cyclone Dani confirmed the greater susceptibility of the Dwarf group compared to the Tall group, but also substantial variability within those two groups, and depending on age.

Table 1: International codes, names and origins of the coconut varieties

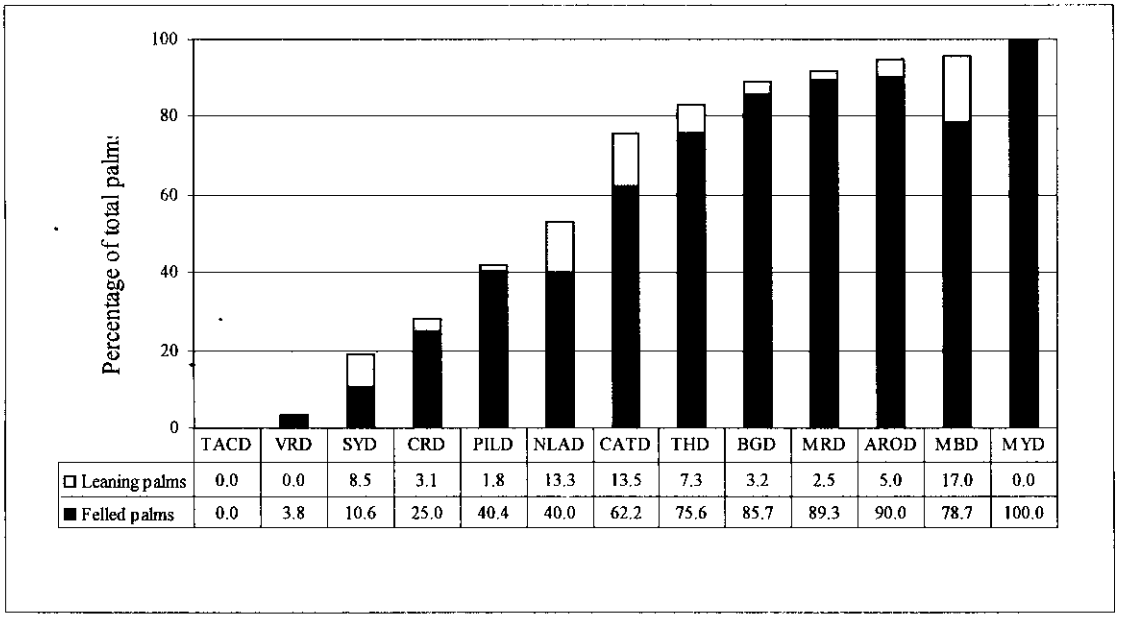
Code	Variety	Origin	
DWARFS			
NLAD	Niu Leka Dwarf	Fiji	SW Pacific Islands
SYD	Samoan Yellow Dwarf	Samoa	
VRD	Vanuatu Red Dwarf	Vanuatu	
MBD	Madang Brown Dwarf	Papua New Guinea	Papua New Guinea
CATD	Catigan Green Dwarf	Philippines	Philippines
PILD	Pilipog Green Dwarf	Philippines	
TACD	Tacunan Green Dwarf	Philippines	
MRD	Malayan Red Dwarf	Malaysia	South-East Asia
MYD	Malayan Yellow Dwarf	Malaysia	
AROD	Aromatic Green Dwarf	Thailand	
THD	Thailand Green Dwarf	Thailand	
BGD	Brazilian Green Dwarf	Brazil	South America
CRD	Cameroon Red Dwarf	Cameroon	West Africa
TALLS			
NCT	New Caledonia Tall	New Caledonia	
RIT	Rennell Island Tall	Solomon Islands	
RTMT	Rotuman Tall	Fiji	
TONT	Tonga Tall	Tonga	
VTT	Vanuatu Tall	Vanuatu	
GPT	Gazelle Peninsula Tall	Papua New Guinea	Papua New Guinea
KKT	Karkar Tall	Papua New Guinea	
BAYT	Baybay Tall	Philippines	Philippines
TAGT	Tagnanan Tall	Philippines	
MLT	Malayan Tall	Malaysia	South East Asia
WAT	West African Tall	Benin	West Africa

Table 2: Characteristics of the collections and hybrids trials observed

Cultivars	Plot	Age	Exposure to strong winds	Total number of palms on the plot	Average number of palms per cultivar
Dwarfs	P31	15	High	737	56
Dwarfs	P51 (Block 1)	5	High	722	55
Dwarfs	P51 (Block 2)	4	High	416	42
Talls	P20	11-13	High	473	94
Talls	P30	14	Medium	387	97
Talls	P40	14-16	Medium	953	87
Dwarfs x Rennell Island Tall	P105	7	High	833	139
Dwarfs x Tonga Tall	P115	6	Medium	850	142
Dwarfs x Kiribati Tall	P125	5	Medium	761	127
Dwarfs x Rotuman Tall	P104	5	Low	859	143
Dwarfs x Gazelle Tall	P114	4	Medium	1007	144
Dwarfs x Markham Valley Tall	P103	4	Low	238	40

Figure 2: Cyclone damage on Dwarf coconut palms. Block of Malayan Yellow Dwarfs

Figure 3: Collection of Dwarf coconuts (15 years old). Percentage of palms felled or left leaning by cyclone Dani depending on the variety



	TACD	VRD	SYD	CRD	PILD	NLAD	CATD	THD	BGD	MRD	AROD	MBD	MYD
□ Leaning palms	0.0	0.0	8.5	3.1	1.8	13.3	13.5	7.3	3.2	2.5	5.0	17.0	0.0
■ Felled palms	0.0	3.8	10.6	25.0	40.4	40.0	62.2	75.6	85.7	89.3	90.0	78.7	100.0

Figure 4: Collection of Dwarf coconuts (5 years old). Percentage of palms felled and left leaning by cyclone Dani depending on the variety

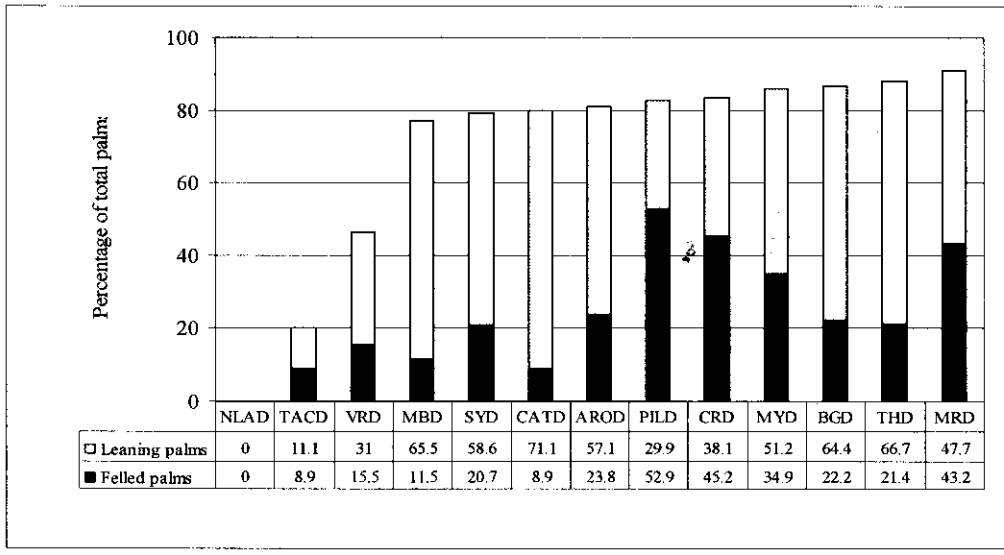


Table 3: Collection of Tall coconuts (11-16 years old). Percentage of palms felled or left leaning by cyclone Dani depending on the variety. The exposure to winds is high for plot P20 and medium for plots P30 and P40

Origin	Variety Code	Plot	Percentage of felled palms	Percentage of leaning palms
SW Pacific Islands	NCT	P20	2.7	0.9
	RIT	P30	1.0	3.0
	RTMT	P30	0.0	0.0
	TONT	P40	6.1	8.2
	VTT (all populations merged)		2.0	0.9
	VTT01 (Surunda)	P40	0.0	0.0
	VTT05 (Bulldoz)	P40	0.0	0.0
	VTT06 (Port Olry)	P40	3.1	0.0
	VTT07 (Tanna1)	P40	0.0	0.0
	VTT08 (Torres)	P20	0.0	0.0
	VTT09 (Tanna2)	P20	7.3	1.8
	VTT10 (Banks)	P20	1.8	0.0
	VTT GC2 (Improved)	P40	0.0	0.0
	VTT Matevulu (Improved)	P20	2.6	4.3
	Vanuatu Red Dwarf x Vanuatu Tall	P20	2.2	4.3
Papua New Guinea	KKT	P30	20.4	12.2
	GPT	P30	33.0	12.5
Philippines	BAYT	P40	3.1	2.1
	TAGT	P40	7.7	3.6
South East Asia	MLT	P40	4.1	1.0
West Africa	WAT	P40	33.3	0.0

Table 4: Coconut hybrids. Percentage of palms felled or left leaning by cyclone Dani depending on the cultivar

Hybrids	Exposure to winds	Age	Percentage of felled palms	Percentage of leaning palms
Dwarfs x Rennell Tall	High	7		
BGDxRIT			3.5	22.5
CRDxRIT			6.8	11.3
MBDxRIT			7.0	23.1
MYDxRIT			23.1	17.9
MRDxRIT (C)			9.9	11.4
VRDxVTT (C)			5.0	2.9
Dwarfs x Tonga Tall	Medium	6		
MRDxTONT			13.8	10.3
MYDxTONT			6.3	7.0
NLADx TONT			1.3	3.2
SYDxTONT			0.8	9.8
MRDxRIT (C)			19.4	14.4
VRDxVTT (C)			15.4	5.6
Dwarfs x Kiribati Tall	Medium	5		
BGDxKIT			5.8	6.6
BGDxRGT			2.9	3.6
MBDxKIT			0.0	1.4
MRDxKIT			4.9	2.1
MYDxKIT			4.8	4.8
VRDxVTT (C)			12.9	2.1
Dwarfs x Rotuman Tall	Low	5		
CRDxRTMT			0.7	0.0
MBDxRTMT			0.7	3.5
MYDxRTMT			2.1	1.4
MRDxRTMT			0.7	2.0
MRDxRIT (C)			10.1	3.6
VRDxVTT (C)			4.9	0.0
Dwarfs x Gazelle Peninsula Tall	Medium	4		
BGDxGPT			2.8	6.3
CRDxGPT			6.3	3.5
MBDxGPT			0.7	6.3
MRDxGPT			4.2	3.5
MYDxGPT			9.7	6.9
MRDxRIT (C)			12.5	6.3
VRDxVTT (C)			8.3	3.5
Dwarfs x Markham Valley Tall	Low	4		
CRDxMVT			4.17	0
MBDxMVT			0	2.86
MRDxMVT			2.13	0
MYDxMVT			5.56	0
MRDxRIT			18.75	2.08
VRDxVTT			2.08	0

Under the conditions of our study, the Tacunan Green Dwarf (TACD) displayed noteworthy resistance to violent winds, a trait already found in the Philippines, its country of origin (G. Santos, personal communication). That Dwarf palm has a broader stem at the base and a moderate height, which might explain a large share of its resistance. In Jamaica, Johnson *et al.* (1994) found a simple relation[4] between two parameters, the diameter of the bole and stem height, and the death rate caused by a cyclone in hybrids between the Malayan Red Dwarf and Tall palms. In Vanuatu, we had stem measurements (stem height, stem circumference 0.20 m from the ground) taken 4 years before the passage of the cyclone for the same collection of Dwarf palms. If those 2 parameters were represented on a simple graph (figure 5), TACD stood out from the other Dwarf coconut palms studied, with a stem height: bole girth ratio (S:B) of 2.56. The other varieties, apart from the Niu Leka Dwarf, had variable measurements, with a S:B ratio between 3.2 and 4.38, but those parameters alone did not explain the great differences in susceptibility found between those varieties. Lastly, the Niu Leka was a very particular case (S:B=1.69). It is very slow-growing palm with a short, broad stem, and a compact crown of fairly rigid fronds with broad leaflets providing a good hold for the wind.

In the case of the Tall palms, the different Vanuatu Tall populations were among the most resistant varieties with, all populations combined, 2% of felled palms and under 1% of leaning palms. The varieties from the Pacific Islands (New Caledonia, Rotuma, Rennell, and, to a lesser degree, Tonga) also resisted well, as did those from the Philippines (Baybay Tall and Tagnanan Tall). The Tall palms from Papua New Guinea displayed little resistance, with up to 33% of felled palms for the Gazelle Peninsula Tall. The West African Tall also displayed little resistance, but it had already been weakened by severe *Phytophthora palmivora* attacks.

For the hybrids, significant differences were also found between genotypes in the plantings set up between 4 and 7 years before the cyclone occurred. At those ages, the MRD x RIT hybrid, which is widespread in the Pacific due to its high yields, seemed to be most susceptible but it also bore the heaviest nut load.

Effect of age

The coconut palms under 4 years old suffered little damage apart from a few torn fronds. The 4 to 5-year-old Dwarf palms were partially uprooted, causing the stems to lean. With age, the density of the root system network and rooting depth increase. Under the conditions in our study, the 15-year-old Dwarf palms were well anchored in the deep soil. Even partial uprooting was therefore more difficult and breakage occurred at the point where the balance between the forces exerted by the wind and the plant's forces of resistance was broken, i.e. in the absence of a bole, at the basal extremity of the stem.

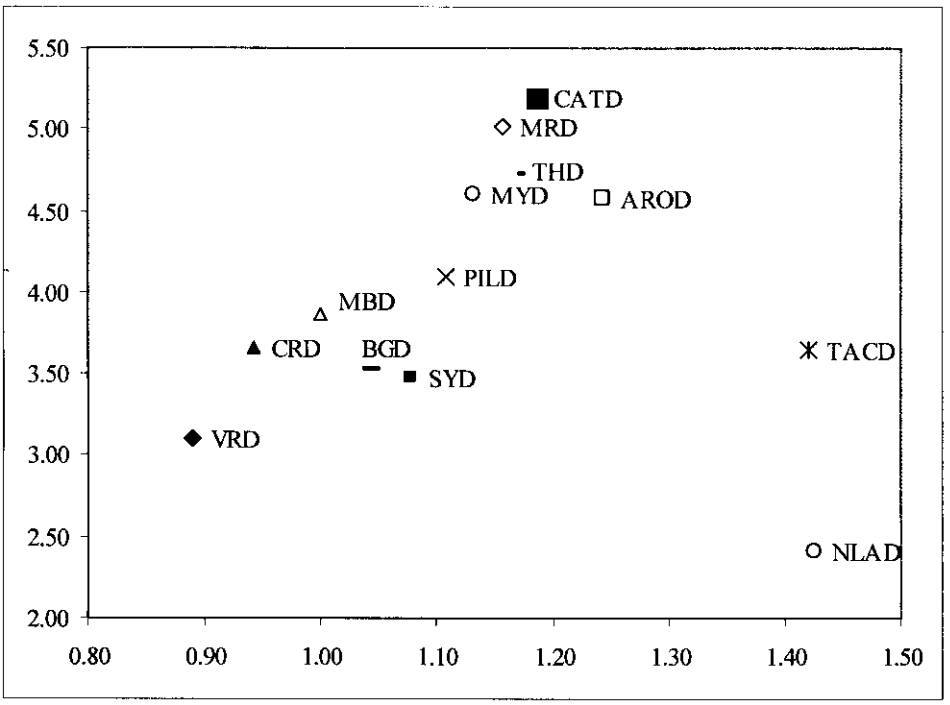
In the case of hybrids, we had two cultivars, VRDxVTT and MRDxRIT, present as controls in the plots planted at different ages. The data in table 4 show that the damage caused by violent winds started to be significant as soon as the coconut palms reached 4 years, was maximum at 5 and 6 years and seemed to decrease slightly from 7 years onwards. Coconut hybrids have a bole which strengthens the stem base. Consequently, for these young palms, we found either partial uprooting or stem breakage above the bole.

In the case of the Tall palms, which were over 11 years old and had a bole and well-developed root system, resistance to violent winds was very good, except for the varieties

[4] Mortality = 0.613 – 0.552 x + 0.264 y (where x= bole girth and y= stem height, in metres)

Figure 5: Cyclone damage on coconut hybrids. Block of Dwarfs x Rennell Island Tall hybrids

Figure 6: Dwarf coconut measurements with x-axis, stem circumference 20cm from the ground (in metres) and y-axis, stem height



from Papua New Guinea. After the passage of cyclone Nigel in 1985, Marty (1986) found relatively severe damage on Vanuatu Tall palms over 8 years old, with 12% of felled palms. However, those plantations had been set up on shallow coral soil and the palms had toppled over due to a superficial root system.

In the absence of any detailed individual morphological measurements, an analysis of factors affecting how coconut palms fare in relation to violent winds can barely be taken any further.

Conclusion

The passage of cyclone Dani at the Saraoutou station provided the opportunity of assessing the susceptibility of different coconut varieties in a particularly uniform environment. For mature palms, it was confirmed that Dwarf palms were clearly more susceptible than Tall palms, mainly due to the lack of a bole at the base of the stem. Differences in susceptibility between Dwarf palms were very clear and depended on the morphological characteristics of the varieties, such as stem base width, stem height and crown characteristics (weight and volume of fronds and fruits). The physical characteristics of the wood (strength, elasticity), which were not measured in this study, can also probably be added.

Lastly, it can be noted that natural selection seems to have played a role in the acquisition of a variety's ability to resist violent winds. Dwarf and Tall varieties, which originate from the South Pacific and the Philippines, where cyclones are frequent, seemed on average to be clearly more resistant than varieties from Papua New Guinea, Southeast Asia and West Africa.

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