WIND PROFILES WITHIN A CASSAVA FIELD AS AFFECTED BY PLANT HEIGHT AND LEAF AREA INDEX

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ABSTRACT

Wind velocity and direction are known to influence the spread of the African cassava virus. A field study was conducted from 1986 to 1988 to determine the importance of crop growth and canopy architecture on wind speed reduction above and within a cassava crop. The vertical wind profiles above the canopy have a logarithmic shape while their shape within the canopy depended upon plant height (H), leaf area index (LAI) and leaf area distribution. Wind velocity reduction by the cassava canopy increased as the wind velocity got higher and was as much as 50% at 0.2H above the canopy.

The horizontal wind profiles show that wind speed reduction started before reaching the leading edge. The maximum reduction was obtained within 2 to 4 m from the leading edge and varied from 50 to 100% depending on the leaf area index, the measuring height within the canopy and the maximum wind speed in the free air.

Keywords : Wind profiles, leaf area index, cassava.

RÉSUMÉ

EFFETS DE LA HAUTEUR DU COUVERT ET DE L'INDICE FOLIAIRE SUR LES PROFILS DE VENT DANS UN CHAMP DE MANIOC.

La vitesse et la direction du vent sont deux facteurs qui affectent la dispersion de la mosaïque africaine du manioc. Une étude a été conduite au champ de 1986 à 1988 pour déterminer l'importance de la hauteur des plantes et l'architecture du feuillage sur la réduction de la vitesse du vent au dessus et dans le couvert du manioc. Les profils verticaux ont une forme logarithmique au-dessus de la canopée alors qu'à l'intérieur du couvert, la forme dépend de la hauteur (H) des plantes, de l'indice foliaire (LAI) et de la distribution de la surface foliaire. La réduction de la vitesse du vent par le couvert de manioc augmente avec la force du vent et peut atteindre 50% à 0,2H au-dessus de la canopée.

Les profils horizontaux montrent que la réduction de la vitesse du vent commence avant le bord d'attaque. La réduction maximale est obtenue 2 à 4 m après le bord d'attaque et varie de 50 à 100% en fonction de l'indice foliaire, de la hauteur de mesure et de la vitesse maximale du vent en amont.

Mots clés : Profils de vent, indice foliaire, manioc.

INTRODUCTION

Several research workers (Fargette, 1985; Fargette *et al.*, 1986) have shown a close relationship between the spread of the African cassava mosaic and wind characteristics. The speed of *Bemisia tabaci* (the disease vector) movement is very low therefore, its spread is closely dependent upon wind velocity and direction (Byrne, 1986; Yao *et al.*, 1986). An understanding of the epidemiology of that virus disease depends on an analysis of the relationships existing between the spread of the pathogen, the movement of the insect vector and the wind characteristics (Yao *et al.*, 1986, 1987). The wind characteristics above a surface (bare soil or crop canopy) are very different from those observed within a canopy (Perrier *et al.*, 1970).

The wind velocity (U) above a surface increases rapidly with height (Z)

$$U(z) = \frac{U^*}{k} \operatorname{Ln}((Z - d)/Zo)$$

where **d** is zero plane displacement; Zo is the roughness length; U* is the friction velocity, **k** is Von Karman's constant (0.4). Legg and Long (1975) have reported that Zo = 0.14H for a soybean canopy. A similar result has been reported by Perrier *et al.* (1970). The wind height is relatively small and the wind profile is not necessarily logarithmic. It is rather determined by the plant architecture and density (Colville, 1968). A field experiment was conducted from 1986 to 88 to study the plant architecture impact on wind characteristics within and above cassava plant canopy and the relative influence on the spread of the African mosaic cassava virus.

MATERIALS AND METHODS

SITE

The experimental site was located at the agronomy farm of the Orstom-Adiopodoumé research center 17 km west of Abidjan (Côte d'Ivoire). The field which covered approximately 1 ha was planted with cassava CB (a cultivar from Congo) in 1986 and cassava Kasimbidji 'Green (a cultivar from Kenya) in 1988. Population density was 10000 plants/ha in each case.

METEOROLOGICAL INSTRUMENTS AND DATA LOGGER

Wind velocity was measured with 10 cup anemometers (Casella London) with mechanical contacts. They were initially calibrated by Casella but a relative calibration of the anemometers was made by exposing all of them at one height. The pulse output was counted on a data logger (HP), the totals were recorded on a magnetic tape every half hour and the data were printed on a paper tape at the end of each run which can last 4 to 7 days.

The anemometers (4) for the vertical wind profiles were mounted on a vertical mast at the center of the experimental field and at heights of 55, 125, 200 and 325 cm above ground level in 1986 and 55, 125, 200 and 500 cm above ground level in 1988 (Figure 1). The anemometers (6) for the horizontal wind profiles were mounted individually on vertical masts and could be moved up and down to a suitable measuring height. The six masts were placed in a row at -4, -2, 0, +2, +4 and +25 m from the leading edge of the crop in 1986 and at -6, -2, 0, 2, 4 and 25 from the leading edge in 1988 (Figure 1).

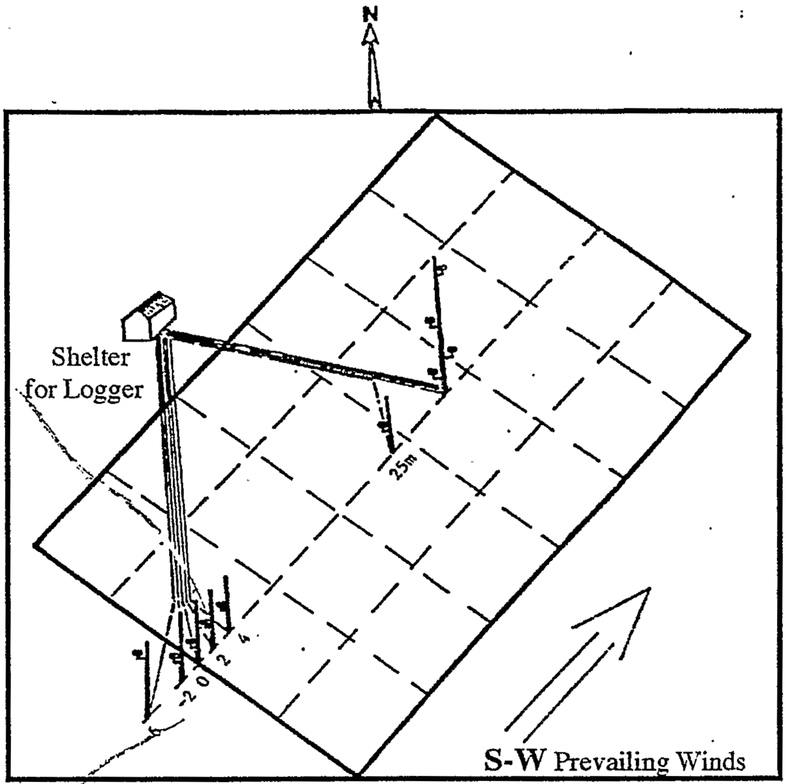

Figure 1 : Experimental Site.
Site d'expérimentation.

One of the disadvantages of the data logger system is that faulty sensors can't be detected until the end of the run when the data are printed on a paper tape. The second major problem is that the batteries must be fully charged at all times to ensure continuous data recording. To do that, an electricity source was needed at the experimental site.

Plant height, leaf area and foliage base were measured to characterize the canopy architecture. Leaf area per plant was computed using the following equation (Yao, 1988):

$$LA_p = \sum_{i=1}^{n} 0.0067\, L_i^{2.042}$$

where LA_p = leaf area (cm^2) $plant^{-1}$

L_i = length (mm) of central lobe of each leaf

i = individual leaf measured

n = total number of leaves $plant^{-1}$

Leaf area index (LAI) was computed as

LAI = 10^{-4} x LA_p.

RESULTS

CROP ARCHITECTURE

Figure 2 presents the canopy charachteristics. Plant height increased steadily reaching a maximum of 2.94 m in 188 days after planting. Foliage base rise was irregular but a sharp rise was always explained by leaf senescence as indicated by the change in leaf number/plant (Figure 2). Figure 2 also shows that leaf area index was dependent upon leaf/plant. Foliage base was lower than 40 cm up today 115 after planting. Starting on day 120 after planting, foliage base rose rapidly, reaching 148 cm 10 days later. LAI, which was greater than 2 since day 85, declined during that period. Starting on day 135 after planting, the lower 2/3 of the crop canopy was leafless. This result suggest that wind velocity reduction in that part of the crop was due to the stems and branches.

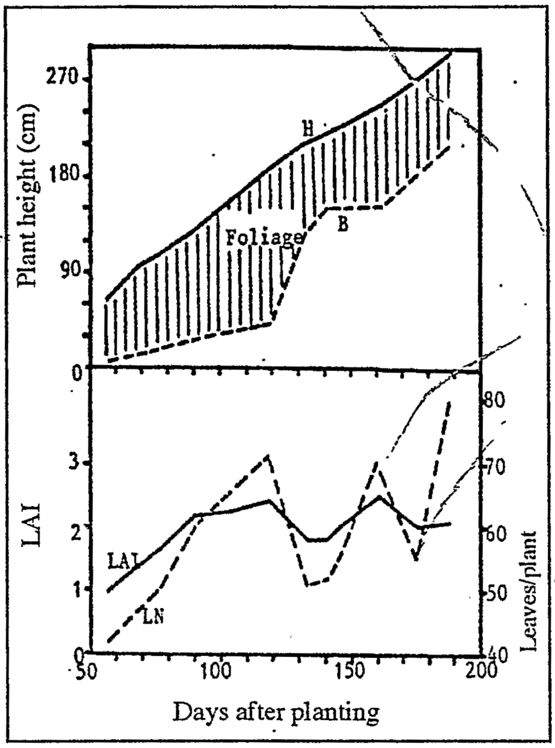

Figure 2 : Characteristics of the cassava canopy. *Les caractéristiques du couvert de manioc.*

H = average plant height
B = average foliage base
LAI = average leaf area index
LN = average leaf number/plant

VERTICAL WIND PROFILES

Above canopy vertical wind speed data plotted on a semilog paper are of linear shape (Figure 3). Figure 3, therefore, demonstrates that the vertical wind profile above the cassava canopy is of logarithmic shape. The result is obtained on the basis of d = 0.75H and the roughness length Zo = 0.12H suggesting that the roughness length of a cassava canopy is about 12% of plant height while the zero plane displacement is about 75% of the plant height. Figure 3 also shows that the friction velocity (U*) increases with wind velocity since the slope of the regression lines (k/U*) declines when the maximum velocity increases and as

$$\mathrm{Ln}\left((Z-d)/Zo\right) = \frac{k}{U^*}\,U(z)$$

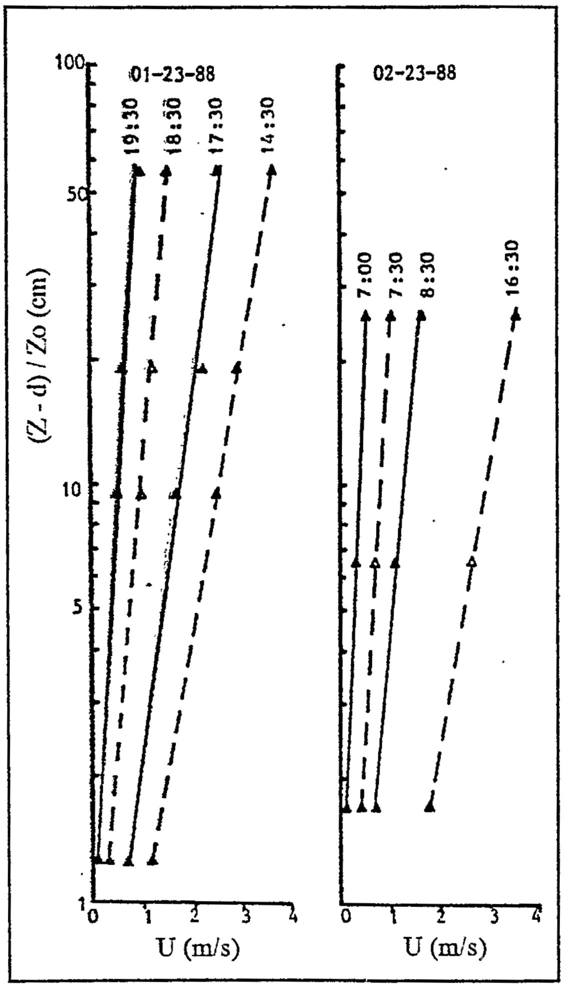

Figure 3 : Vertical wind profiles above the cassava canopy in 1988.
Profils verticaux du vent au-dessus du couvert de manioc en 1988.

d = 0.75H
Zo = 0.12H

Figure 4 shows that the vertical wind profile within the cassava canopy is not logarithmic and is mainly dependent on canopy structure and leaf area index. When the crop was about 120 cm in height and leaf distribution was uniform, wind velocity reduction within the cassava canopy increased steadily with depth (Figure 4.a). For a six-month crop measuring 170 cm in height and with a leaf distribution centered towards the top, as it was after day 140 (Figure 2), wind velocity was relatively higher at the base of the canopy (Figure 4b).

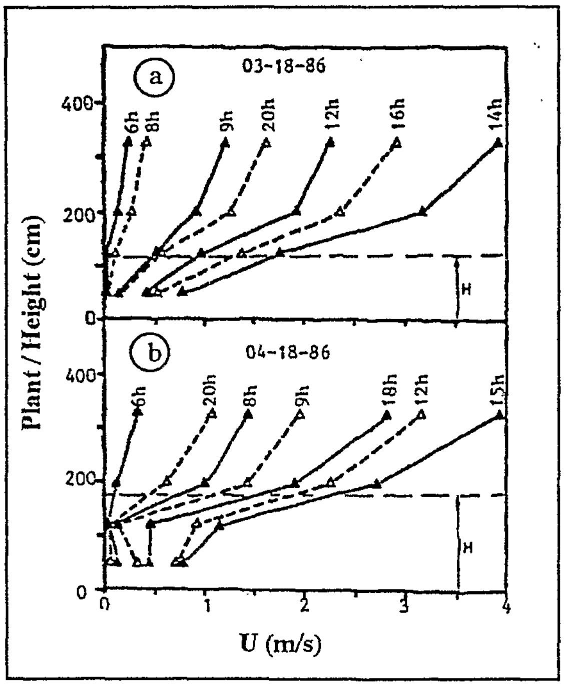

Figure 4 : Vertical wind profiles within the cassava canopy in 1986.

Profils verticaux du vent à l'intérieur du couvert de manioc en 1986.

Figure 5 (a to c) and tables 1a to 1c demonstrate that wind velocity reduction above the cassava canopy was a function of plant height and was not affected by any variation in velocity since U(z) was linearly related to U(500). As one can see, the slope of the regression line declines with depth (Tables 1a to 1c). When the measurements were made within the cassava canopy, wind velocity reduction was still a function of height but the linear relationship did not always exist at the base of the canopy (Table 1a). This result is evidence that canopy structure and especially LAI (Figure 2) have affected wind velocity reduction. Figure 5d confirms the inflection of the wind profile from within to above the cassava crop observed when the crop was sufficiently tall and leafless at the bottom.

HORIZONTAL WIND PROFILES

Figure 6 shows that the cassava canopy constitutes a wind break where wind velocity reduction starts before the leading edge. As reported by Kawatani and Meroney (1970) the horizontal distribution of the mean velocity profiles may be grouped into two sections. An initial region about 4 m wide on each side of the leading edge where large changes in the mean velocity occur and a second region to the leeward where changes are smaller. The velocity reduction was maximum only a few meters (2 to 4 m) after the leading edge. The variation in velocity reduction at the same distance from the leading edge is an indication that canopy characteristics (which are modified under higher winds) have significant importance. The anemometer position is very important, as demonstrated in figure 7. Even at height of 1.2H or 0.2H above the canopy, wind speed reduction within four meters before the leading edge can be as high as 60%. The reduction increases with distance and depth within the canopy (Figure 7).

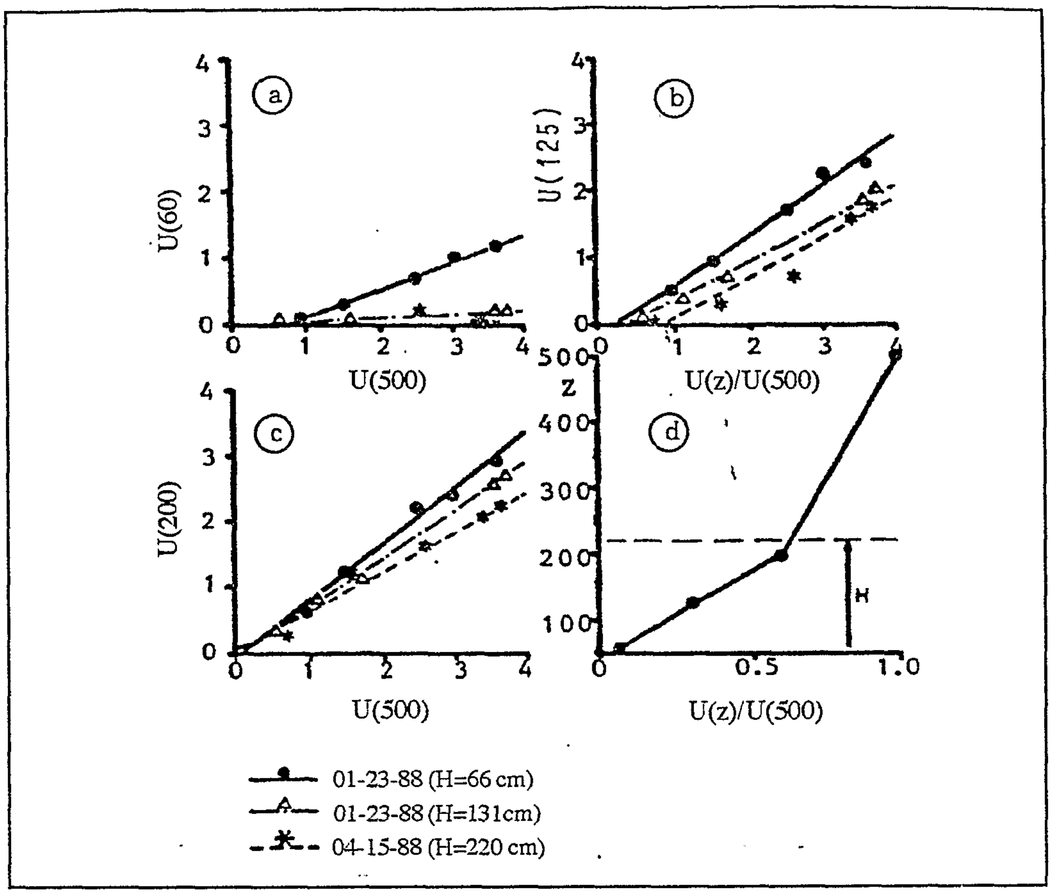

Figure 5 : Relationship between wind speed (m/s) at 500 cm and 60 cm (a), 125 cm (b), 200 cm (c) and average wind speed distribution (d) within the cassava canopy in 1988.
Relation entre la vitesse du vent (m/s) à 500 cm et 50 cm (a), 125 cm(b), 200 cm(c) et la répartition de la vitesse moyenne à l'intérieur du couvert de manioc en 1988.

Table 1a : Statistics of the regression analysis between U(60) and U(500) in 1988.

Date	Intercept	Slope	r	Slope=1	Origine=0
01/23	-0.3005	0.4116	0.99	no	no
02/23	-0.0659	0.0696	0.98	no	no
04/15	NOT LINEAR				

Table 1b : Statistics of the regression analysis between U(125) and U(500) in 1988.

Date	Intercept	Slope	r	Slope=1	Origine=0
01/23	-0.2156	0.7606	0.99	no	yes
02/23	-0.2204	0.5774	0.98	no	no
04/15	-0.5744	0.6076	0.97	no	no

Table 1c : Statistics of the regression analysis between U(200) and U(500) in 1988.

Date	Intercept	Slope	r	Slope=1	Origine=0
01/23	-0.1189	0.8644	0.99	yes	yes
02/23	-0.0995	0.7550	1.00	no	no
04/15	-0.0164	0.6089	0.98	no	yes

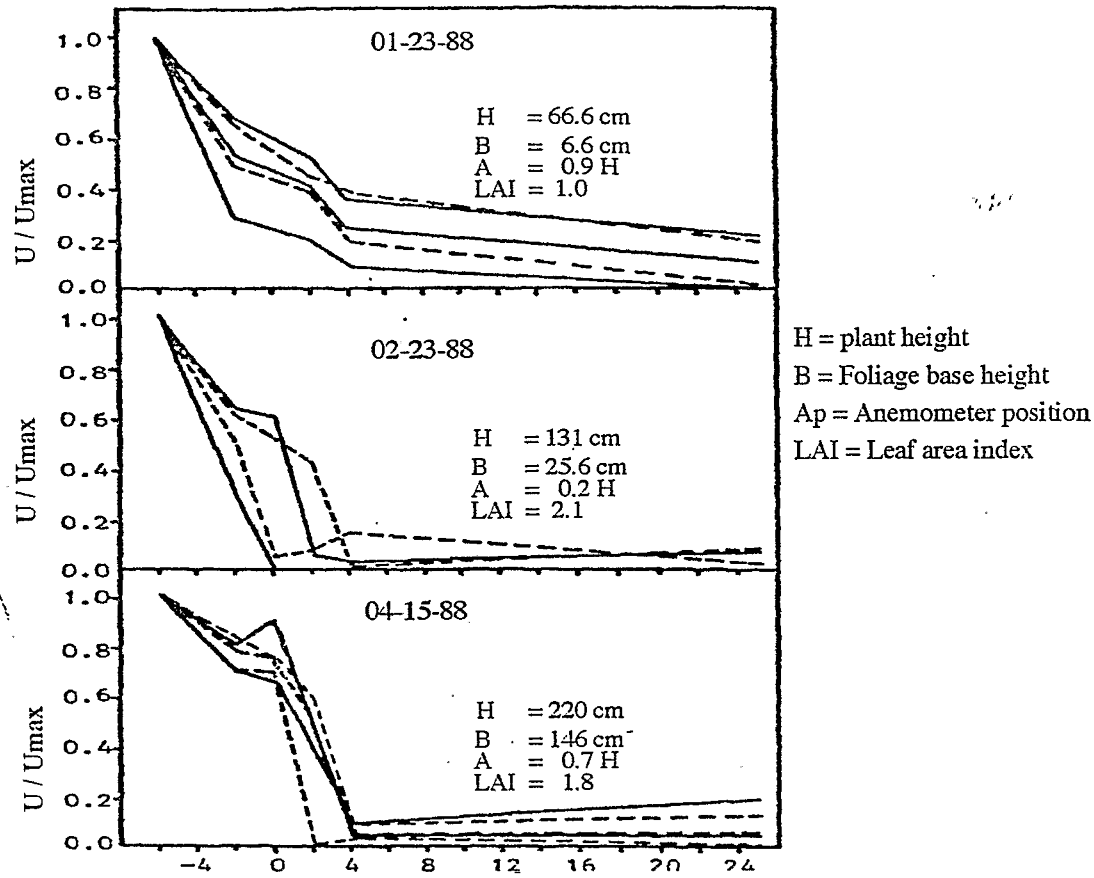

Figure 6 : Normalized horizontal wind profiles within the cassava canopy as affected by canopy.
Profil horizontal normalisé du vent à l'intérieur du couvert de manioc.

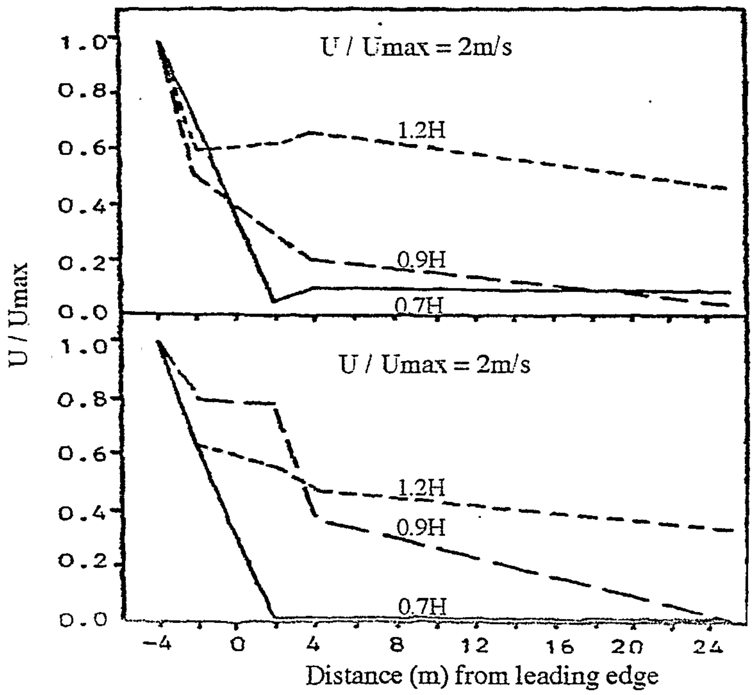

Figure 7 : Normalized horizontal wind profiles within the cassava canopy as affected by anemometer position in 1986. (H = plant height).
Profil horizontal normalisé du vent à l'intérieur du couvert de manioc en fonction de la position de l'anomètre en 1986 (H = hauteur de la plante).

DISCUSSION

The linear relationship between wind velocity (U) and elevation (z) on a semilog paper (Figure 3) corroborates with the logarithm shape of vertical wind profile above a surface. This result is an evidence that the roughness length (Zo) of a cassava canopy is 0.12H where H is the plant height while the zero plane displacement d = 0.75H.

As reported by several scientists (Yao *et al.*, 1990) rapid basal leaf senescence can be associated with both soil water content below the wilting point and high leaf area index, resulting in an effective reduction of leaf number per plant. High LAI causes leaf loss due to low light intensity in the basal part of the canopy (Connor and Cock, 1981). Low soil water content following a drying cycle also leads to rapid leaf loss (Yao *et al.*, 1988). The senescence of basal leaves modifies the foliage structure leading to a relatively higher wind velocity at the base of the canopy (Figure 4). However, the reduced wind speed was always less than 1 m/s no matter the wind velocity (up to 4 m/s) above the cassava canopy.

Several research workers (Kawatani and Meroney, 1970; Mullet, 1986; Fargette *et al.*, 1986) have shown that the white fly accumulation and the african cassava mosaic virus disease spread decline away from the field border. Fargette *et al.* (1986) have reported a declining gradient in the spread of the disease in experimental fields of sizes ranging from 0.1 to 4 ha in the absence of any windbreak. As we have shown in this study, the cassava canopy constitutes a windbreak leading to the reduction of the incoming wind velocity up to 50%. This wind speed reduction associated with plant height and leaf area index can explaine the gradient in white flies accumulation and the african cassava mosaic spread observed in cassava field (Fargette et al., 1986). As a matter of fact, the modification in the wind structure approaching the leading edge and the substantiel reduction in the wind velocity are favorable conditions to the lending of the white fly and therefore the spread of the disease (Kawatani and Meroney, 1970; Muller, 1986). The extent of the accumulation is a function of the importance of the obstacle and therefore, plant height, leaf area index and canopy roughness.

CONCLUSION

This study shows that wind velocity reduction within and above a cassava canopy is significant and often higher than 50%. The sharp decline in wind velocity in the canopy where daily averages are less than 5 m/s may have a significant effect on the flying strategies of airborne insects and therefore on the spread of some plant diseases such as the African cassava mosaic virus.

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