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Full Length Research Paper

Towards sustainable production of new varieties of *Dioscorea rotundata* resistant to yam mosaic in rural areas of Côte d'Ivoire

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Yam mosaic virus (YMV) is a major factor limiting for stable production of yam. Specie *Dioscorea rotundata* is particularly susceptible to the virus yam mosaic virus (YMV). This study was conducted in Bringakro (6° 401'N, 5° 091'W, 150 m alt.), the transition forest-savanna zone in Côte d'Ivoire. Fifty-nine yams elite of *D. rotundata* coming from the germplasm collection of the International Institute of Tropical Agriculture (IITA) and four local varieties were used in 2000 and 2001. Their resistance to yam mosaic virus was evaluated in field trials in Côte d'Ivoire. The experimental design used was the augmented design with four replications each year in 2000 and 2001. Statistical analysis was done with SAS v10 for anova. Visual score of YMV on the leaves, canopy surface measure and yield were the parameters collected. Symptoms varied from mosaic on leaves to shoestring. It depended on the environment, that is, climate and plant host. All year long, tuber yield according to cultivar was very significant (P<0.02). The new assessions of yam were more productive than local ones. In conclusion, some of the new yams can be recommended to farmers in Côte d'Ivoire to improve yam cropping system and their incomes.

Key words: Yield, white yam, yam mosaic virus, canopy surface, Côte d'Ivoire.

INTRODUCTION

Yam (*Dioscorea spp*.) production in Côte d'Ivoire has increased in the past 10 years from annual output of 4,706,585 kg in 2002 to 5,674,696 kg in 2013 (FAO, 2014). The cultivated yams belong to the Dioscoreceae family and to the *Dioscorea* genus (Coursey, 1967). The most cultivated species in Côte d'Ivoire are the *D. rotundata* (white yam), *D. cayenensis* (yellow or guinea yam) and *D. alata* (water yam). Yams are valuable sources of carbohydrates to the people of the tropical and subtropical Africa, Central and South America, parts of Asia, the Caribbean and Pacific Islands (Coursey, 1967; Adelusi and Lawanson, 1987). White guinea yam (*Dioscorea rotundata* Poir.) is a domesticated specie of the Dioscoreaceae produced mainly in West and Central Africa, principally in Nigeria, Togo, Benin Republic, Ghana, Côte d'Ivoire and Cameroon (Odu et al., 2006). Among the many pests and pathogens that affect yams in general, viruses are of major importance (Odu et al., 2006). Viruses reported to infect yams include *Dioscorea latent virus* (DLV), genus *Potexvirus, Dioscorea alata*

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virus (DAV), genus *Potyvirus*; *Cucumber mosaic virus* (CMV), genus *Cucumovirus Dioscorea dumetorum virus* (DdV), genus *Potyvirus*; *Dioscorea bulbifera bacilliform virus* (DbBV), genus *Badnavirus*; *Dioscorea alata bacilliform virus* (DaBV), genus *Badnavirus*; and *Yam mosaic virus* (YMV), genus *Potyvirus* (Thouvenel and Fauquet, 1979; Brunt et al., 1990; Hughes et al., 1997; Odu et al., 1999). *Yam mosaic virus*, genus *Potyvirus*, is an ubiquitous pathogen. Infection with yam mosaic reduces the plant's vigour and its subsequent tuber size. The YMV causes the most-widespread and economically important viral disease affecting white yam in West Africa.

Facing emerging and re-emerging diseases associated with increased human migrations, movement of plant material and climatic changes, it appears that it is crucial to get resistant or, at least, tolerant plant material for farmers. Protection of crops against pathogens may be achieved by means such as application of chemicals, phytosanitation and the use of biological control agents or incorporation of host plant resistance. The use of resistant varieties has been considered to be the most effective and environmental-friendly means of disease control as part of integrated pest management (Odu et al., 2004a).

This work was done in Côte d'Ivoire area country located in a tropical-warm, sub-humid zone in West Africa. The purpose of this study was to identify *D. rotundata* genotypes that have high yield on poor soil and at the same time are tolerant or seem resistant to YMV. Those varieties should be used in sustainable yam production by farmers.

MATERIALS AND METHODS

This study was conducted in Bringakro (6° 401'N, 5° 091'W, 150 m alt.), the transition forest-savanna zone in Côte d'Ivoire. It is an equatorial transition climatic zone with a bimodal rainfall pattern.

Total rainfall ranged from 900 to 1300 mm annually. The annual rainfall of 2000 and 2001 has been described (Ettien et al., 2013). Annual average temperature and hygroscopy were respectively 27°C and 70%. The vegetation of the site was a long fallow of *Imperata cylindrica.*

Fifty-nine yams of *D. rotundata* species coming from the germplasm collection of the International Institute of Tropical Agriculture (IITA) and four local varieties (Kponan, Kangba, Krengle, Djate) were used in 2000 and 2001 for evaluation in field trials in Côte d'Ivoire. These new yams were selected on the basis of their past performance in various field trials at IITA. The size of each improved seed was 70 g while the size of the local checks was 280 g.

Experimental design

The experimental design used was the augmented design with four replications each year in 2000 and 2001. This experimental design was described elsewhere (Nokoe 1999; and Ettien et al., 2013). The planting bed size was 15 m × 10 m. The total surface used per subplot was 150 m^2. Each planting bed was a replication and four replications were established. Seeds of *D. rotundata* were planted in lines at 30,000 plants/ha for nine months of vegetation (May-January). A line corresponded to one variety used in each block. However, the canopy in year 2001 at 6 months was higher than that in year 2000.

Virus symptoms identification and scoring

Plants were scored visually for virus infection on the basis of IITA (1996) scale. Systemic symptoms were apt to differ considerably on the different leaves of the same plant: mosaic, vein-banding, green spotting or flecking, curling and mottling. YMV caused several symptoms including, leaf and vein chlorosis, leaf distortion and malformation, shoestrings of leaf as well as plant stunting (Figure 1). Shoestrings (SS) represented a very severe form of the disease. Plants with score of 1 (no symptom) were considered as resistant, while those scoring between 2 and 5 (2: moderate or mild symptoms, 3: severe symptoms, 4: very severe symptoms, 5: distortion, malformation of leaf or stem) were evaluated as susceptible. We observed each foot range on the ridge by counting the number of infected plants. Then we gave a score between 1 and 5. Observations of disease began when the plants began full vegetation phase. The full vegetation began two months after planting. The frequency of observations was four per month. The symptoms score was determined each week. Then, in the end, all the measurements averaged the scores obtained for each variety for a single mean score. This annotation lasted three months, from June to August each year (2000 and 2001).

Canopy surface rate

The coverage rate was measured on a scale of 1 to 5. It was observed that score 1 showed that the ridge was not covered and the ground was clearly visible, while score 5 showed that the ridge was fully covered, and the ground was not visible. Canopy surface rate was scored respectively on the 2nd and the 4th month after planting.

Yield evaluation

At harvest time, the tubers of each variety were bagged in lines and weighed in order to get the mean yield of

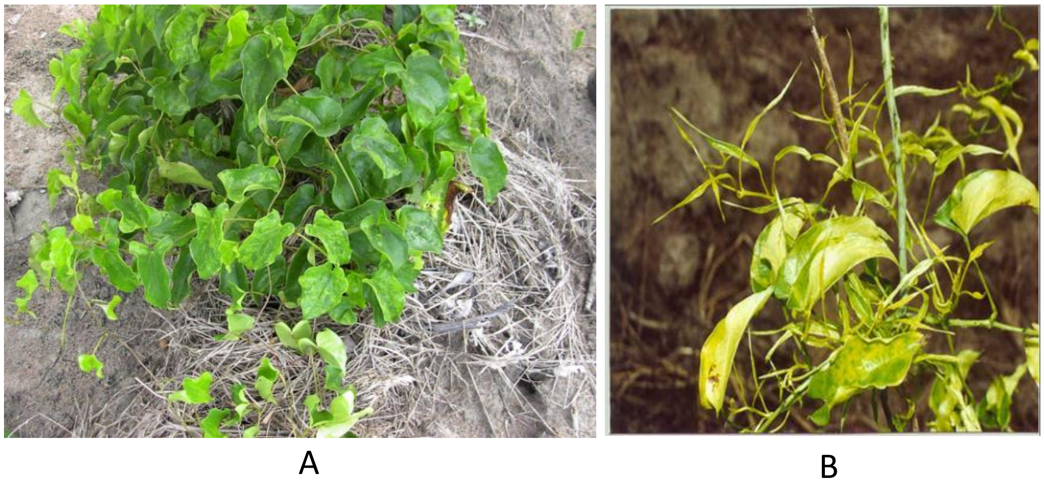

Figure 1. Yam mosaic virus symptoms in the field: (A) mosaic, (B) shoestring on *D. cayenensis-rotundata* plant.

each variety after statistical analysis. This was done at each harvest time of the two years.

Statistical analysis

Considering the diseases, canopy and yield as the studied factors, the analysis of variance (ANOVA) factorial type for yield, effect of virus and cover were made using the SAS software 8.2 version. Means values were separated by the method of least significant difference (LSD). Varietal clustering according to its reaction to virus diseases was done with SPSS v10 considering the different scores of each line relying on IITA scale throughout the two years.

RESULTS

Symptoms varied from leaf to leaf, shoot to shoot and plant to plant, even if they were of the same varieties and originated from the same locality as shown in Figure 1. The chlorotic areas are usually clearly defined and varied in size from that of a whole leaflet to small flecks or spots. Sometimes, leaves between the affected ones may seem normal and give the appearance of recovery.

As for canopy, there was no noticeable difference at the 4th month during the two years. Meanwhile, at the 6th month, the canopy density was significantly higher in 2001 than in 2000 with $P<0.05$. These results are illustrated in figure 2. The same figure shows a yield regression of *D. rotundata* from year 2000 to 2001.

According to yam mosaic disease score in field, three classes could be considered. The most infected lines were *96-0040, 95-18555, 95-18531* and *87-00109*, and the less infected ones were *89-02565, 96-01524, 95-18531* and *87- 00109.* All the other varieties were moderately infected. The local controls *Djate, Krengle, Kponan* and *Kangba* were scored equal or under 3 (Figure 3).

All year long, tuber yield according to cultivar (P=0.02) showed that 95-19177 and 95-19156 had a yield superior to 30 t/ha. For lines *96-00575, 95-01937, 96-02097, 96-00480, 96-00020, 96-00165, 96-00629* and *95-18555*, the yield varied from 25 to 23 t/ha. The ten less productive cultivars (8-13 t/ha) were *96-00058, Kangba, 95-02040, Krengle, 95-18531, 96-00053, Djate, 96-01522, 96-1524* and *95-01967*. The incidence of YMV varied between 0 and 100% depending on the variety. According to Figure 4, most of the local control had a low yield compared to improved yam.

In Table 1, Pearson correlation was made by using SPSS version 10.0 (SPSS Inc., Chicago, Illinois). The result showed highly correlation between the different parameters and yield. The mosaic symptoms scores showed negative correlation with yield (R - 015669), while the canopy was positive. These results are logical.

DISCUSSION

Yam mosaic disease is caused by an aphid-transmitted potyvirus that infects several species of *Dioscorea,* particularly *D. alata*, *D. cayenensis*, *D. rotundata* and *D. trifida* (Amusa et al., 2003). YMV is a major factor limiting for stable production of yam and *D. rotundata* is particularly susceptible to the virus (Mignouma et al., 2002). Considerable genetic diversity is known to exist among West African populations of YMV (Goudou-Urbino et al., 1996; Duterme et al., 1996; Bousalem et al., 2000). Despite the diversity of YMV, sources of resistance have

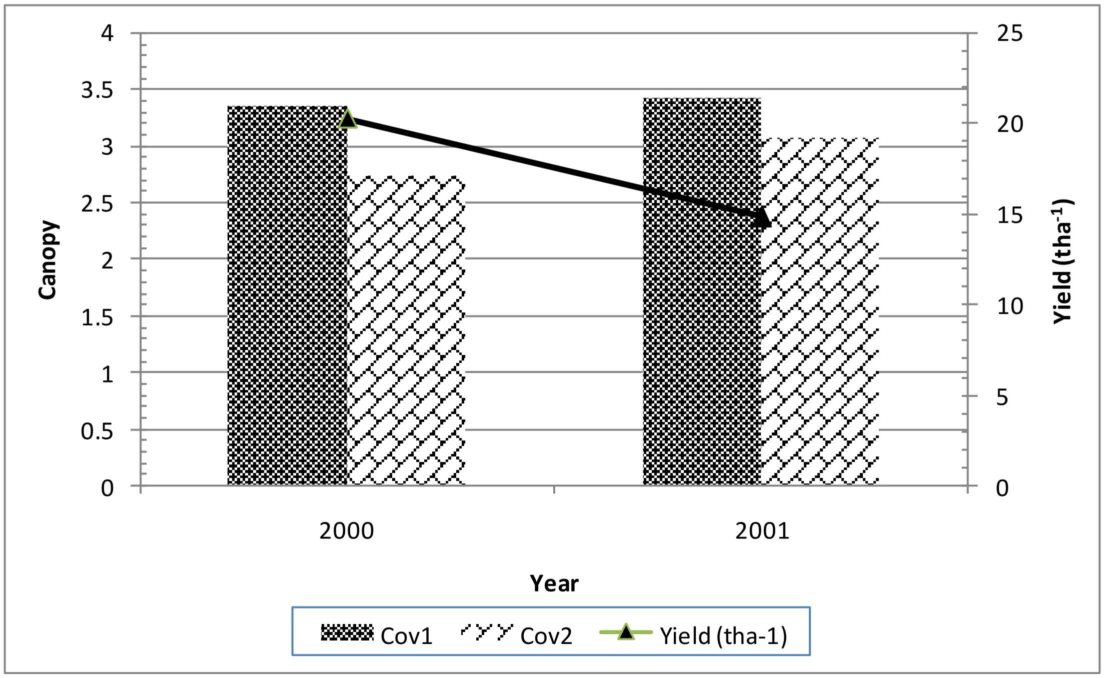

Figure 2. Canopy and yield of *D. rotundata* in 2000 and 2001 (P>0.05 for Cov1; P<0.05 for Cov 2 and Yield). Note: Cov - cover.

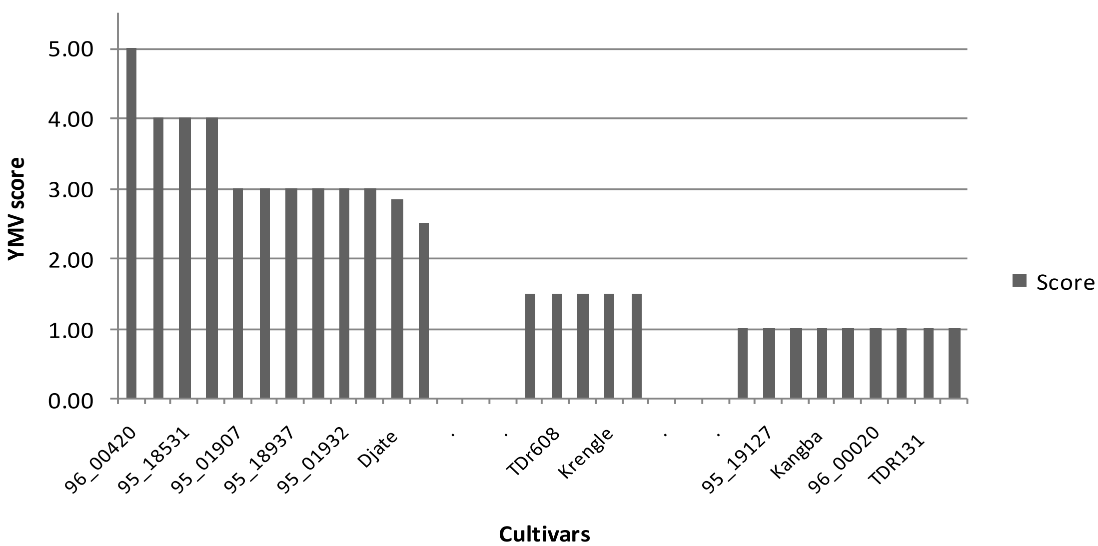

Figure 3. Ranking of cultivars based on the scores of yam mosaic virus.

been identified among tetraploid *D. rotundata* landraces and breeding varieties (IITA, 1996), but a high degree of resistance such as immunity or complete absence of symptoms has not been observed (Mignouna et al., 2001). Because different viruses may elicit similar symptoms, the disease phenotype can provide only

Table 1. Pearson correlation coefficient and probability between tuber yield and Mos, Cov1 and Cov2 respectively.

Variable	Yield correlation	
	R	P> ltl
Yam mosaic virus	-0.15559	0.0524
Cover 1	0.38961	<0.0001
Cover 2	0.31193	<0.0001

limited, although important, information for disease diagnosis (Pallas and Garcia, 2011). Variation in symptoms observed in this study may be due to differences in virus strain, plant age, and environmental factors such as soil fertility, soil moisture availability, radiation and particularly temperature. Sometimes, the affected leaves may seem normal and give the appearance of recovery. This behavior is influenced by the ambient temperature and host-plant resistance. The symptomless leaves on infected plant could result from a tolerance mechanism operating in the particular genotypes. This confirms the findings of Mignouna et al. (2001). The severity of symptoms does not necessarily correlate with the virus title, indicating that the disease can be the result of specific interactions between the virus and host components. These assumptions concur with the findings of Thouvenel and Dumont (1988), Odu et al. (2001) and Amusa et al. (2003). According to Thouvenel and Dumont (1988), this virus is mechanically transmitted. The final result of virus infection is a reduction in plant growth, lower yield, inferior product quality, and economic loss to individuals who work in the plant industry (Bowers, 2001; Gergerich and Dolja, 2006).

Canopy surface depends on the plant health and also on the environmental factors. It has been noted in the results that canopy surface was positively correlated with the yield. At the same time, a negative correlation was observed with symptoms scores. Moreover, the yield declined from 2000 to 2001 as shown in Figure 2 despite the coverage which seemed better in 2001. The impact of YMV did not negatively influence these varieties that have shown their high potential resistance to YMV and its severe form called shoestring. The effect of YMV has been studied elsewhere and qualified as a major constraint to the productivity of yams in West Africa (Eni et al., 2013; Babajide et al., 2011). Indeed, the coverage rate would negatively influence the process of developing the yield of yams or did not play a significant role in the synthesis of carbohydrates. This means that getting a high rate of coverage does not bode high performance, but it would depend on many other factors such as solar radiation and the source-sink relationship as demonstrated by Hgaza et al. (2010). It was noted that in August, the height of rainfall was very important unlike in 2001. In fact, the month of August in this region of the country marks the peak of the dry season which starts in July and ends in September. In 2000, a regular distribution of rain according to the seasons was noted. These rains could have disturbed, in 2001, physiological cycles of yams which could result in water stress. Indeed, it has been shown that nitrogen needs in yams nutrition are important from the tuber initiation phase which starts the 8th week after planting (Nwoke et al., 1984).

Ranking the different lines on the basis of the score showed that most of the progenies are in classes 3 to 5. It is known that *D. rotundata* is susceptible to YMV. In Figure 4 where only yield was considered to classify assessions, it was noted that it was not the assessions which had higher score of symptoms that got the best yield. The results confirmed the tolerance of most of the lines tested in Côte d'Ivoire environment. In this study, most assessions of *D. rotundata* genotypes screened exhibited symptoms associated with viruses infecting yams. This could mean that most of the lines used in this study were tolerant compared to the local controls. Although many viral infections progress effectively without symptoms, induction of specific defense mechanisms of plants can be efficient (Pallas and Garcia, 2011). The rate at which viruses infect plants in the field depends greatly on the availability of abundant infection of foci and vectors. Naturally, infected yam plants become available sources of inoculum when used as planting materials in the cited successive years (Odu et al., 2004b). In as much as the indexing of yams from the field is based on symptom expression, this result may partly explain why assessions with high scores were not those with the lowest yield.

The mosaic is negatively correlated to the performance of varieties with a significant difference, while coverage is positively correlated with performance. The greater the effect of the mosaic, the greater the yield decreases, and the more the coverage is important, the more the yield is significantly higher. In the absence of virus, the potential of yam is predicted to be high. A virus not only needs to escape the defenses that plants erect, but must also tackle different processes to complete its productive cycle. The initiation of this cycle depends on the nature of the genetic material of the virus. As such, virus diseases are common in all the yam growing areas.

Conclusion

In this study, different assessions of *D. rotunda* have been tested in field condition in Côte d'Ivoire. Compared to the local varieties used by farmers, the progenies of IITA gave better results despite yam mosaic disease. The

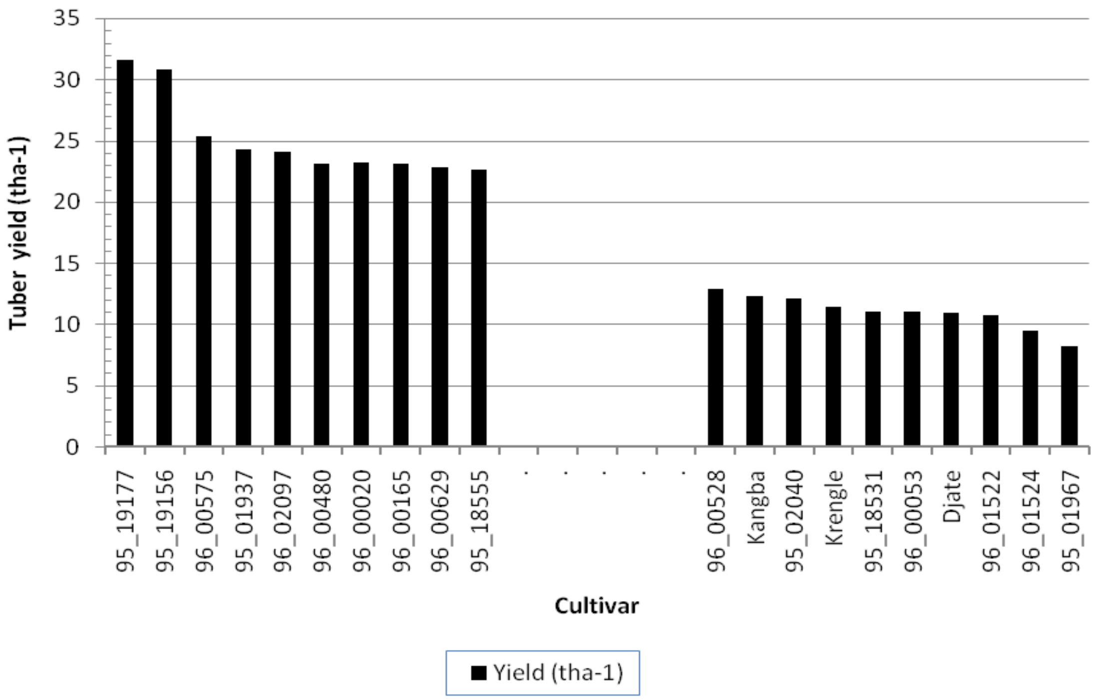

Figure 4. Across year tuber yield according to cultivar (P=0.02).

incidence varied between 0 and 100% depending on the kind of yam. There was significant variation in yield among the assessions compared to local control despite YMV disease even at a high level score. Meanwhile, field disease scoring was not the only reliable parameter for screening varietal material. For further experiment, even in field, it will be more consistent to use modern techniques such as serological test and PCR in addition to visual score.

The implications of these results for international germplasm exchange are that more restriction on transfer of *Dioscorea* spp. from one country to another is required; rapid, reliable and robust screening methods for indexing yam plants are needed for the regulation of international exchange and production of virus-free germplasm. Despite the good of the evolution, dispersion and epidemiological properties of viruses, they are believed to be determined through a combination of constraints imposed by the host(s), the vectors, the environmental conditions and human activity. This could be the next object of studies on virus in agricultural environment in Africa.

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