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IMPACT OF VIRUS INFECTION ON YAM (*Dioscorea rotundata* POIR) PERFORMANCE IN NIGERIA

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Abstract
Yam is important for food security in Nigeria. The trial was laid out in Randomized Complete Block Design (RCBD) with seven treatments (seven local varieties), and three replications to assess the impact of virus incidence and severity on performance of yam varieties in the field during three growing seasons (2014, 2015 and 2016). The performance indicator that was studied was yam yield and virus symptoms used for evaluation were mosaic and mottling, vein-clearing, and vein-banding. Plants that grew from virus-negative seed yams expressed the presence of virus symptoms on the field. Germination percentage was lowest in Gbakumo yam variety and played a greater role in the determination of yam yield in all yam varieties. The presence or absence of virus in the seed yam before planting affected the level of yam germination and yam yield. Virus incidence, which increased yearly, was negatively correlated to germination and yield. Average tuber weight was positively correlated to germination count (%) in some varieties. For the three years, the varieties; Mailemu, Bangwasi and Allushe showed evidence of tolerance to virus infection with high performance in terms of germination and yield. New local yam varieties therefore need to be further investigated for inclusion in food security staples in Nigeria.

Keywords: Incidence, severity, virus, yam yield, and Guinea Savanna

Introduction
Food security is of utmost importance for the survival of mankind and the sustenance and promotion of his economic activities including food production (Otaha, 2013). About 80% of Nigeria's population live in the rural areas with most of them aged, uneducated peasant farmers who lack capital, skills, energy and other viable ingredients to produce the large quantity of food that will meet the requirement of the growing population (Otaha, *ibid*). Yam (*Dioscorea spp*.) is an important tuber crop that has the potential to contribute to food security in Nigeria and West Africa (Beckford *et al.,* 2011; Verter and Bečvařova, 2015).

However, one of the important factors that militate against the capacity of yam to contribute sufficiently to food security demands in Nigeria is virus infection. Vegetative multiplication of yam tubers forms the most used method of yam propagation by Nigerian farmers. This is associated with poor sanitation in storage and during national and international movements of yam germplasm, which favour virus evolution and diversification. Virus infection in yam has been shown to cause severe economic losses (Craig, 1964, cited in Aighewi *et al*., 2015). Among the viral diseases of yam, potyvirus constitute the largest and economically most important genus. *Yam mosaic virus* (YMV) is one of the most important members of potyvirus causing economic losses of yam in Africa and other parts of the world where yam is grown (Adeniji *et al*., 2012). The effects of *Yam mild mottle virus* (YMMV) are commonly found on *D. alata,* showing symptoms of chlorosis, vein banding, flecking and leaf puckering (Kumar, 2015). The *Chinese yam necrotic mosaic virus* (CHYNMV) was reported in Japan where it was found to infect Chinese yam (*D. opposite*) which exhibited symptoms such as chlorotic and necrotic spot, mosaic, and mottling. Other viruses that have been reported to infect yams in Nigeria include; *Dioscorea latent virus* (DLV)- Genus *Potexvirus*, *Dioscorea alata virus* (DAV)- Genus *Potyvirus, Cucumber mosaic virus* (CMV)- Genus *Cucumovirus, Yam mosaic virus* (YMV)- Genus *Potyvirus, Dioscorea dumetorum virus* (DdV)- Genus *Potyvirus, Dioscorea bulbifera bacilliform virus* (DbBv) Genus- *Badnavirus* and *Dioscorea alata bacilliform virus* (DaBV) Genus-

Badnavirus (Mukhtar *et al*., 2012; Asala *et al*., 2012).

The CHYNMV has been shown to cause up to 45% tuber loss in Japan through seed tuber infections. In Côte d'Ivoire, YMV and CMV were reported to cause yam tuber loss of between 20% and 48% for all varieties of yam tested (Séka *et al.,* 2014). Adeniji *et al*., (2012) showed that yam tuber yield loss due to YMV was between 50% and 65% in the two studies in the southern rain forest of Nigeria. However, the effect of virus infection of yam seed and leaves on yam tuber yield has not yet been systematically studied in the Guinea Savanna Zone of Nigeria. Such a study will provide needed information that will assist farmers and government to put measures in place that will improve yam production in this part of Nigeria which is the yam food market of Nigeria. This study therefore is aimed at evaluating the yield response of some commonly grown local yam varieties to virus infection in the Guinea Savanna zone of Nigeria.

Materials and Methods

Experimental site and selection of seed samples

The experiment was carried out at the Teaching and Research Farm, Faculty of Agriculture, University of Abuja (9.0765°N, 7.3986°E). The soil of the location was sandy loam, with average pH of 5.0-5.8. The trial was set to assess the virus incidence, severity and the impact of virus disease on the performance of yam varieties on the field during three growing seasons of 2014, 2015 and 2016. Treatments consist of 7 local varieties from five States (Kwara, Kogi, Nassarawa, Niger and Benue) and Abuja FCT. Based on planting preference by farmers, local varieties Gbakumo, Makakusa, Allushe, Bangwasi, Peppa, Umulla and Mailemu were selected for the study. Before planting, the tubers to be planted were selected randomly and tested in the laboratory for their virus status using Polymerase Chain Reaction (PCR) method (Abarshi, 2010). All yam samples were indexed for *Yam mosaic virus* (YMV); *Badnavirus* (DaBV) and *Yam mild mottle virus* (YMMV), which had been identified in previous epidemiological studies in this agroeconomic zone of Nigeria (Asala *et al*., 2012). The tubers were then separated into virus-positive and virus-negative groups.

Land preparation, experimental design and planting

The trials were laid in Randomized Complete Block Design (RCBD) with seven treatments and three replications. The fields were prepared by ploughing the soil in heaps of ten per row (total of 210 heaps) and spacing of 1m x 1m. Propagation was done by cutting each tuber into several pieces or planting setts of approximately 500g each, with each piece having at least a dominant eye or bud. Planting was done at the beginning of the raining season (usually mid-April).

Germination of yam seed

Germination count started at 4 weeks after planting (WAP). Counting was done weekly for two months. The total number of seeds of each variety that germinated between the time of planting and the time of reading was taken and expressed as a percentage of the number of seeds of each variety that was planted and recorded as the germination percentage.

Incidence of virus diseases

Examination of the plants for evidence of virus infection started 10 weeks after sowing (WAS). The presence of characteristic symptoms such as mosaic, vein-clearing, green-banding, green spotting or flecking, curling, mottling, leaf and vein chlorosis, leaf distortion and malformation was sought for on the leaves and used as evidence of virus-infection in the field. Virus disease incidence (DI) was defined as the percentage of the total number of plants that showed symptoms of virus disease.

Disease severity

The severity of symptoms was assessed using the scoring scale of the International Institute of Tropical Agriculture (IITA, 1996) modified by Asala *et al*., (2012). The scores were on a scale ranging from 1 through 5: 1 = No obvious symptoms, 2 = Symptoms on 2%-24% of leaves, 3 = Symptoms on 25%-50% of leaves, 4 = Symptoms on 51-75% of leaves and 5 = Symptoms on 76-100% of leaves. Disease severity was defined as the sum of all disease ratings expressed as a percentage of the total number of plants that were assessed.

Tuber yield and average tuber weights at harvest

The yam tubers at maturity were harvested in groups according to their varieties. Tuber yield per variety per annum and over the three-year period were expressed in kg/ha. From the yield values, the average tuber weights (kg) of each variety were calculated.

Statistical analysis

All data obtained were subjected to statistical analysis of variance (ANOVA) using the IBM-SPSS Statistic (version 23) package. Means separation analysis employing Duncan multiple range test (DMRT) was used to determine the level of statistical difference between parameters. P values less than or equal to 0.05 were considered significant. Pearson's correlation analysis was employed to assess the relationships between measured parameters. The maximum probability level accepted for significant relationship was set at $p \leq 0.05$.

Results and Discussion

Virus identification in yam seeds

The seed tubers of Gbakumo, Makakusa and Peppa tested positive for YMV, YMMV and (DaBV), while Allushe, Bangwasi, Umulla and Mailemu tested virus negative. Whereas Gbakumo showed the lowest germination percentage during the first two years of the trial, the mean germination percentage for the three years of study was not significantly different from one yam variety to the other irrespective of the virus status of the yam varieties. This suggests that it is not the presence or absence of virus in the planted seed yam alone that determines the presence or absence of virus infection after germination. Other factors such as species differences and weather factors may play interactive roles (Sri *et al.,* 2017). The predominant symptoms were mosaic, mottling, vein-clearing, and vein-banding. Other symptoms were shoestring, distortion and malformation, necrosis, and chlorosis.

Tuber sprouting in yam varieties

Germination percentage was of similar values for all yam varieties across the 3 year trial except for Gbakumo with significantly lower germination percentage in the first two years of the trial (Figure 1). But by the third year of trial, the germination in Gbakumo increased to a level similar to those of other yam varieties. The mean germination percentage for the three years was also significantly lower in Gbakumo than in other yam varieties at $p<0.05$ (Table 1). This may be due to the adaptation of this variety to the environment or

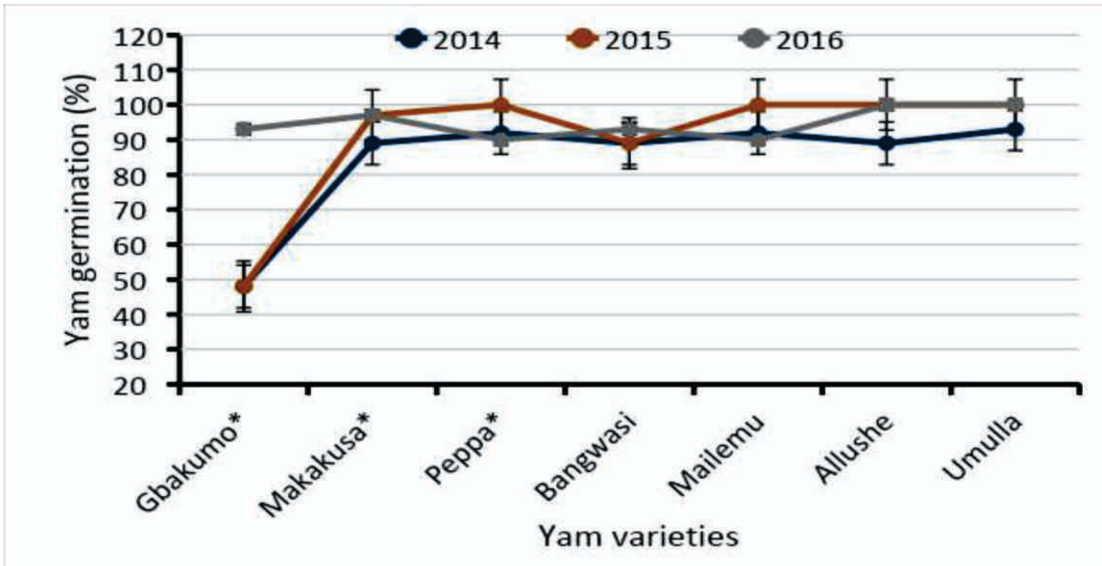

Fig.1: Seed yam germination percentage in local yam varieties
*** - yam varieties with virus-positive seeds**

Interaction of virus infection parameters in yam varieties

Virus incidence

Virus incidence was significantly highest in Gbakumo yam variety in the first two years of the trial (Figure 2), but reduced significantly in the third year. Mean virus incidence for the three years of the trial showed that Gbakumo, Yakakusa and Peppa have significantly higher virus incidence than the other yam varieties at $p<0.05$ (Table 1). This finding, especially in the infected Gbakumo is unexpected as previous studies by Asala and Alegbejo (2016), indicated that YMV and YMMV are transmitted by infected planting materials that are replicated and spread from one planting season to another. The adaptation of this group of yam varieties in the present study may have to do with other influences such as weather and host resistance (Odu *et al*., 2011; IITA, 2015). The weather factors include; rainfall, which when heavy, dislodges insect pests which are hosts and sources of viruses in the field, from the yam plants (Asala, 2014).

Table 1: Interaction of Viruses with the performance of yam varieties in Guinea Savannah Zone of Nigeria

Variety	Mean Germination (%)	Mean Incidence (%)	Mean Severity (%)	Mean Yield (kg/ha x 10^3)	Mean tuber yield (kg)
Gbakumo	62.89^{b}	87.00^{a}	26.33^{a}	12.78^{d}	1.89^{d}
Makakusa	94.11^{a}	79.11^{b}	25.22^{a}	26.16^{c}	2.79^{c}
Peppa	93.89^{a}	68.58^{c}	23.76^{ab}	35.60^{ab}	3.84^{ab}
Bangwasi	90.44^{a}	64.87^{d}	13.98^{d}	31.56^{bc}	3.42^{bc}
Mailemu	94.11^{a}	63.78^{d}	14.33^{d}	41.56^{a}	4.41^{a}
Allushe	96.22^{a}	64.67^{d}	18.96^{c}	34.23^{ab}	3.54^{bc}
Umulla	97.67^{a}	62.00^{d}	24.04^{ab}	39.93^{ab}	4.06^{ab}

Mean = Average of replicates in 3 years of trial ±SEM. Means in the same column with different alphabets are significantly different from one another at P<0.05

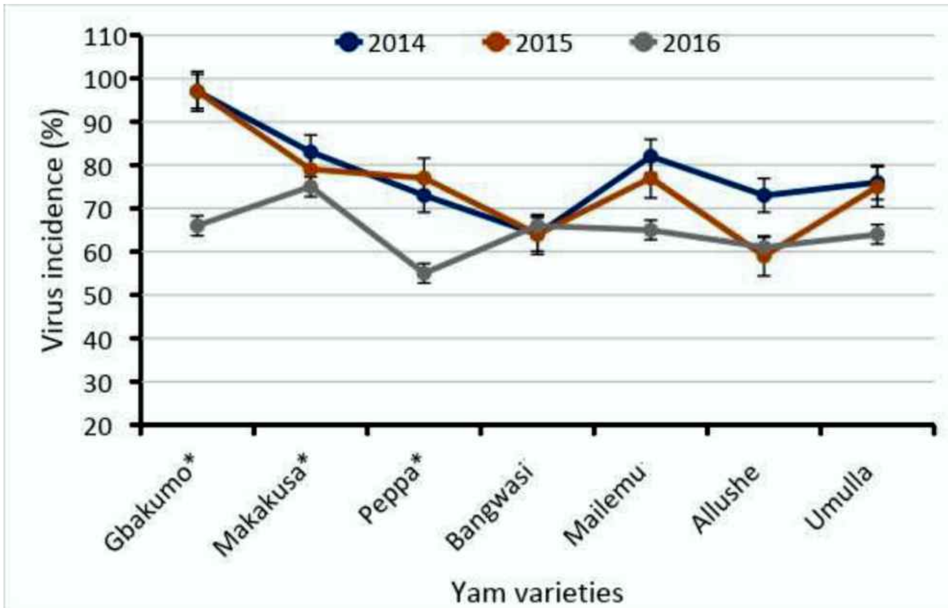

Fig. 2: Incidence of virus infection in local yam varieties
*** - yam varieties with virus-positive seeds**

Disease severity

Disease severity was highest in Gbakumo over the first two years of the trial (Figure 3). Allushe had the lowest disease severity for each of the three years of the trial. The mean disease severity values for the three years of the trial showed no significant differences between Gbakumo, Makakusa, Peppa and Umulla (Table 1). But their level of severity of infection was significantly higher than those of the remaining yam varieties at $p<0.05$. Positive relationship, though not significant in this study, was seen between virus incidence and disease severity. However, virus incidence and severity independently exhibited reciprocal relationship with tuber yield except for Mailemu yam variety in which high virus incidence associated with low disease severity resulted in higher yam yield. This variety appeared to have exhibited tolerance to the viruses in this study.

Impact of virus parameters on yam yield

The yearly, as well as the three-year mean yields of Gbakumo were the lowest ($p<0.5$) when compared with other yam varieties (Figures 4 and 5). This was followed by Makakusa, while Mailemu, Umulla, Peppa, Allushe and Bangwasi constituted the group with the highest yam yield for the entire trial period. However, Mailemu, Umulla and Peppa performed better in the first year of the trial than in subsequent years (Figure 4). The result of correlation analysis showed positive and significant correlation of +564 at $p<0.01$ between seed germination, mean total and mean tuber yields for the three years of the trial (Table 2). There was a negative and significant correlation between virus incidence and total tuber yield at $p<0.01$ (Table 2). The severity of virus disease also correlated negatively but significantly with mean tuber weight at the level of $p<0.05$ (Table 2, Figures 4 and 5). From the three years study, three varieties (Mailemu, Allushe and Umulla) whose seed-tubers were free of virus infection before planting, performed better than Gbakumo, Makakusa and Peppa in terms of germination and tuber yield. Therefore, there is a need to evaluate more local varieties that may perform better against virus infection, biotic stress, and other extraneous factors before and after planting. Disease severity has the greatest impact on yield with a significant inverse relationship between them. Therefore, tubers that are harvested from plants with high severity symptom scores should not be replanted in other to reduce the intensity and spread of virus infection which may result in reduced yam yield. These precautions are important if yam is to contribute more efficiently to food security in Nigeria and West Africa. In this study, plant sprouting exhibited more prominent influence on yam yield than virus infection. This may be explained by the associated reduced availability of healthy plant leaves which are required for effective interception of light for adequate production of plant nutrients (Adeniji *et al*., 2012; Njukeng *et al*., 2014). Therefore, more studies must be done to assess and confirm the performance response of more local yam varieties to virus infection and other factors with the intent to identify which of them can efficiently complement the mainstream varieties that Nigerian farmers grow. Relevant government agencies and Agricultural extension officers will have to motivate and support farmers to grow these yams. This will form an important step towards improving food security level in Nigeria, especially in the presence of current global economic depression.

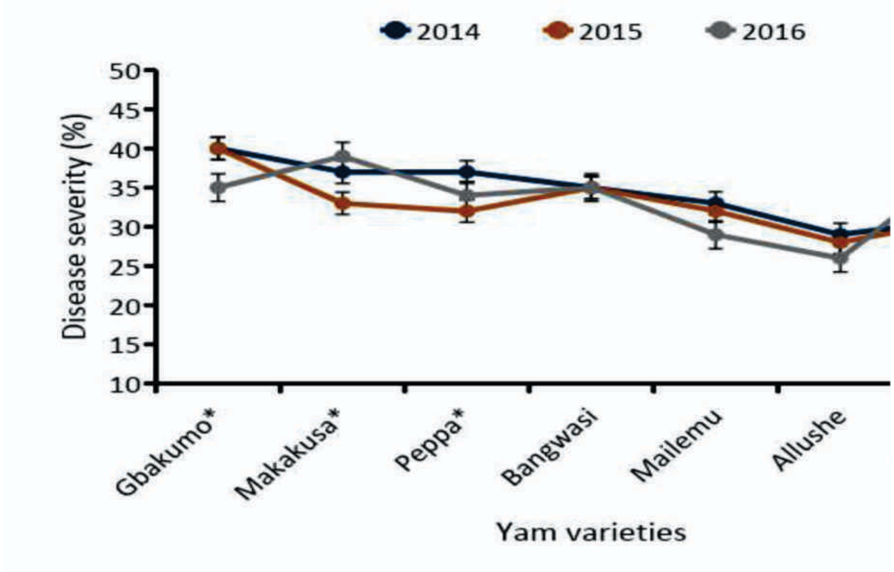

Fig 3: Severity of virus infection in local yam varieties
*** - yam varieties with virus-positive seeds**

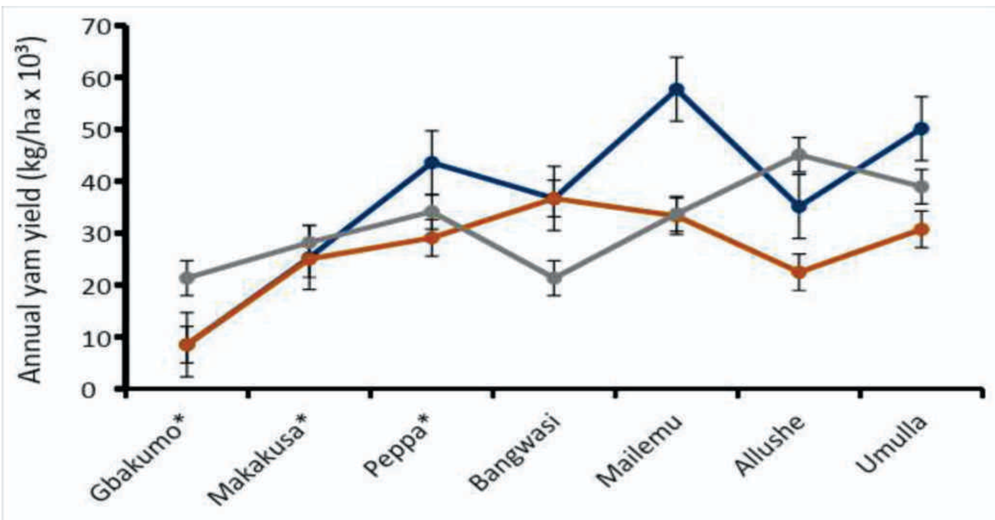

Fig. 4: Total annual yield in local yam varieties
*** - yam varieties with virus-positive seeds**

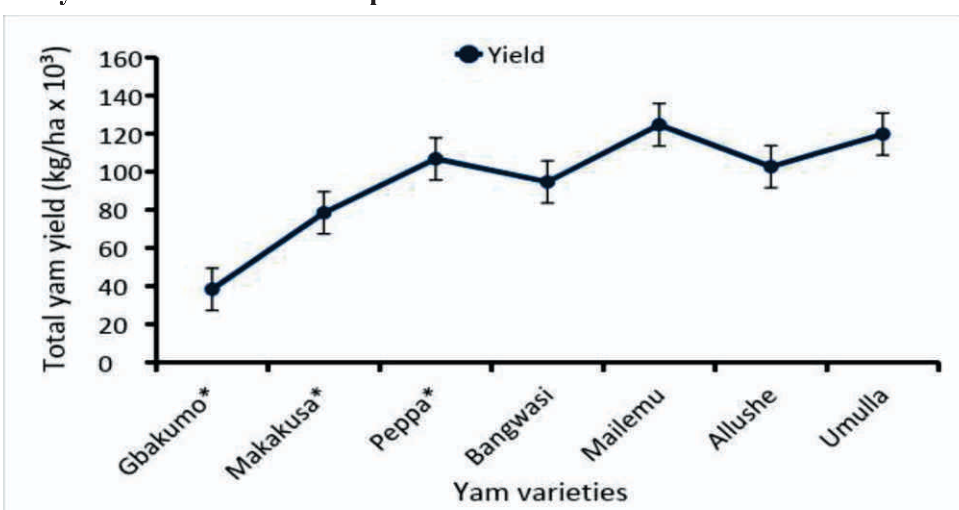

Fig. 5: Overall three-year yields in local yam varieties
*** - yam varieties with virus-positive seeds**

Table 2: Correlation coefficients of virus indices and performance of local yam varieties

	Variety	Year	Germ	Incidence	Severity	Total Yield	Mean Tuber Weight
Variety	1						
Year	.000	1					
Germ	.197ns	+.273*	1				
Incidence	.104ns	-.471**	-.619**	1			
Severity	.196ns	+.827**	+.474**	-.380**	1		
Tuber Yield	+.281*	-.146ns	+.564**	-.335**	-.152ns	1	
Mean Tuber Weight	+.269*	-.242ns	+.375**	-.229ns	-.295*	+.968**	1

**** Correlation is significant at the 0.01 level (2-tailed)**
*** Correlation is significant at the 0.05 level (2-tailed)**
ns – Not significant

Conclusion

Yam varieties (Peppa, Bangwasi, Mailemu, Allushe and Umulla) that are not usually counted among the popular species and therefore not widely grown in the Guinea savanna zone of Nigeria, performed better than the more popular ones (Gbakumo and Makakusa) in terms of seed-tuber sprout, low virus incidence, low disease severity and yield at the end of three years of field trial. If further studies support this finding, farmers should be encouraged and empowered to grow more of these varieties as a way of contributing to food security in Nigeria.

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