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Effect of sources of sweetpotato planting material for quality vine and root yield

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Abstract: Commercialization of sweetpotato vines is persistent if multipliers show evidence of superiority of their vines. This study aimed at evaluating the effects of net tunnel source and of pathogen-tested planting material compared to "apparently" healthy vines on yield and health status at three defined environments in Northern Ghana during the rainy season of 2015. Sweetpotato virus disease (SPVD) and weevils were considered. Four varieties were investigated, the pathogen-tested vines of Dadanyuie, Bohye and Ligri, and "apparently" healthy vines of Apomuden from the negative selection technique. All planting materials taken from the net tunnel and open field were from the same location. Eight treatment combinations were arranged in a RCBD with 3 replicates. Planting distance was 0.30 m x 1 m. Weeding was done and fertilizer was applied as necessary. General and three-way analysis of variance were computed using Genstat. Highly significant differences were found among varieties and trial sites for plant establishment, foliage yield, root yield, weevil, and SPVD. The two sources were not significantly different. For varieties across sites, net tunnel source was better than open field. The apparently healthy vines might be effective as pathogen-tested vines. Net tunnels may have a distinct advantage for multiplication and maintenance.

Keywords: sweetpotato, clean planting material, net tunnel, negative selection, genotype by environment interaction, farmer varieties

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1 Introduction

Sweetpotato is mostly grown in small plots by subsistence farmers in low-input agriculture systems (Carey et al. 1998; Abidin 2004; Ebregt 2007). This crop produces far greater amounts of food per unit area per unit time than grain crops (e.g. 194 MJ/ha/day for sweetpotato vs 159 for maize or 135 for wheat) (Scott et al. 2000). Maintaining good caloric intake in developing countries, particularly in Sub-Sahara Africa, has proved to be a challenge due to variable weather conditions, drought, floods, declining soil fertility and landholding size, high levels of poverty and malnutrition, pests and diseases. Sweetpotato has the potential to contribute much more to alleviate hunger and address food and nutrition security in Sub-Saharan Africa (Abidin 2013). Recently, our proof of concept project, Jumpstarting orange-fleshed sweetpotato (OFSP) in West Africa through diversified markets, has shown that OFSP producers will invest in planting material when they have a market for their crop. Since farmers can maintain and multiply their own planting material, there is a need to demonstrate the value of investing in good quality planting material in order to generate repeat sales for vine multipliers.

The northern regions of Ghana are characterized by small land holdings and low input - low output farming systems, which adversely impact food security, and indeed, income generation. In particular, they are subject to a seasonal cycle of food insecurity of three to seven months for cereals (i.e., maize, millet and sorghum) and four to seven months for legumes (i.e., groundnuts, cowpeas, and soybeans). These crops in the savannahs are often produced in a continuous monoculture, steadily depleting soil natural resources and causing the yields per unit area to fall to very low levels. The poverty profile of Ghana identifies the three northern regions as the poorest and most hunger-stricken areas in the country. Gender inequalities are also apparent in these regions, since women have limited access to resources and therefore limited capacity to generate income on their own. Techniques are needed to reliably boost productivity of crops, including sweetpotato. This work was undertaken to determine the potential for using cultural practices, specifically net tunnels and visual selection, to improve quality of sweetpotato planting material, and yield of crops derived from it.

2 Methods and Materials

Studies were conducted in 2015 at three defined environments in the northern parts of Ghana, i.e., Nyankpala, Northern Region (9°23'35"N, 1°00'21"W), Navrongo, Upper East Region, (10°48'27''N, 1°6'24''W) and Wa, Upper West Region (10°4'37''N, 2°30'21"W). Figure 1 shows the map of Ghana indicating the trial sites.

From the evidence-base experiences, the northern parts of Ghana has relatively lower sweetpotato virus diseases (SPVD) pressure compared to the southern parts of Ghana. However, in the northern Ghana, the sweetpotato weevil incidence is more pronounced as compared to the southern regions. The above reasons could be fairly explained due to having a difference in rainfall distribution pattern between the above two regions. In northern Ghana, people have experience with a uni-modal rain season distribution pattern with long drought spells. The annual average rainfall ranges from 950 mm to 1200 mm (GSS 2010). Meanwhile the southern Ghana has bi-modal pattern, although it is little weak. In this paper, we focused on the northern regions because of some reasons, i.e. sweetpotato was an important crop for people in Upper East Region, and less importance in Upper West and Northern Regions. The Regional Analytical Report by the Ghana Statistical Service described the soil in Nyankpala as sandy-loam with deposits of gravel while that of Navrongo and Wa are predominantly savannah ochrosols and laterites (GSS 2010). Furthermore, during our routine work done in these chosen trial sites, we became aware of the soil in Nyankpala relatively fertile compared to Navrongo and Wa. Table 1 shows the results of soil analysis for the three trial sites.

The incidence of SPVD was recorded in Nyankpala and Wa, while in Navrongo, the sweetpotato weevil was noticed to be a problem. Four farmer varieties were used: Apomuden (Kamala Sundari (CIP440243), orange-fleshed sweetpotato), Bohye (CIP199062.1) light orange flesh), Dadanyuie (KEMB 37) white-fleshed sweetpotato) and Ligri (Cemsa 74-228 (CIP400004), white flesh). Planting materials were multiplied in insect-proof net tunnels and in adjacent field plots at the primary multiplication located at Bontanga near Tamale in northern Ghana. Except for Apomuden, the

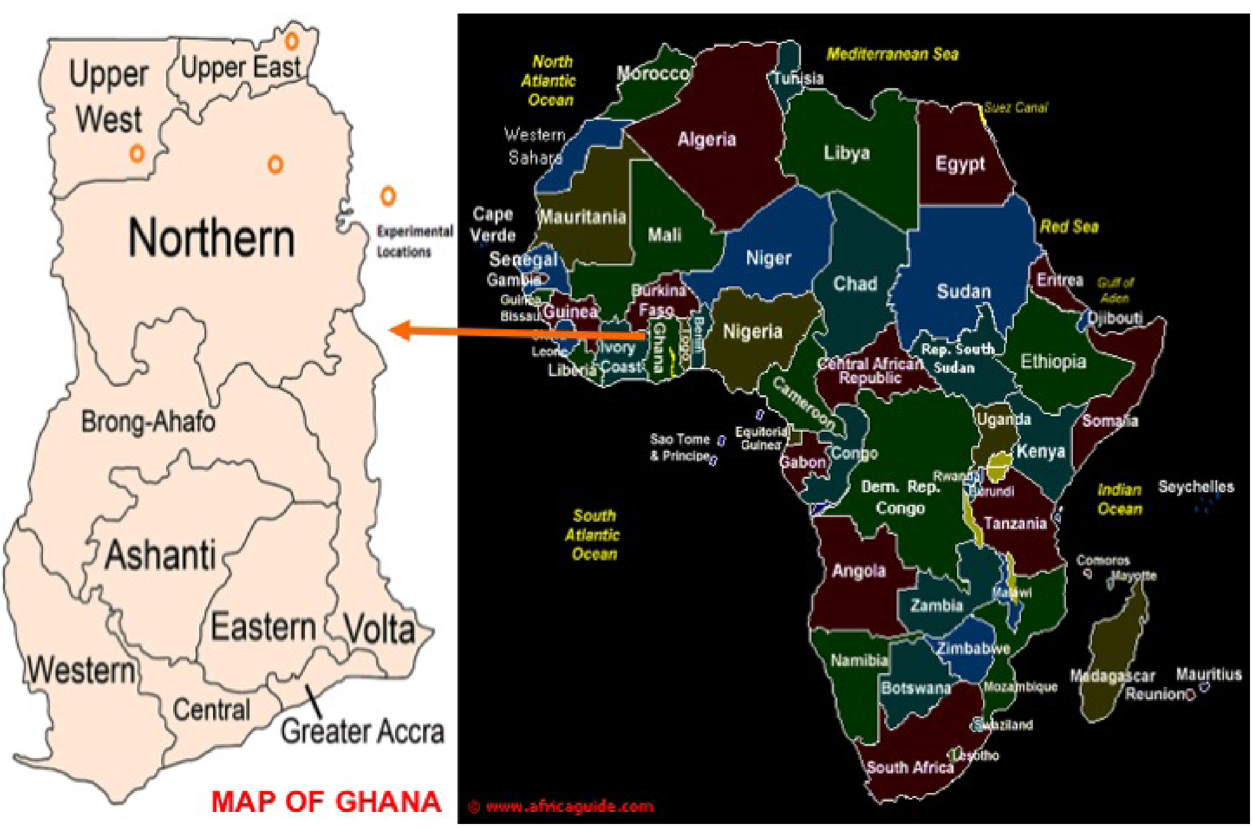

Figure 1: Map of the trials conducted in Ghana

Table 1: Soil analysis for the three trial locations

Trial Location	pH	%OC	%N	Mg/Kg P	Mg/Kg K	Cmol+/Kg Ca	Cmol+/Kg Mg	%Sand	%Silt	%Clay
Nyankpala	5.75	0.027	0.025	7.85	39.33	1.66	0.51	62.37	36.7	0.92
Navrongo	5.63	0.468	0.046	6.811	20	1.56	0.24	83.48	16.1	0.4
Wa	6.59	0.468	0.045	3.602	40	1.36	0.4	75.08	24	0.88
Mean	**5.99**	**0.321**	**0.039**	**6.088**	**33.11**	**1.53**	**0.38**	**73.643**	**25.6**	**0.733**

Notes: OC = organic Carbon; Cmol+/Kg = centi-mol charge per kg

planting materials grown in net tunnels came from the tissue culture lab after cleaning them from sweetpotato virus diseases (SPVD). The field multiplications were done using the "apparently" healthy planting material, which was a non-pathogen-tested material. "Apparently" healthy field-derived planting material was produced by rogueing plants showing virus symptoms (namely Negative Selection). A total of 8 treatment combinations were arranged in a randomized complete block design (RCBD) with 3 replicates. The 4 X 5.1m plots were planted to 17 cuttings per row by 4 rows. Plants were spaced at 0.30 m within plants and 1m between rows. The experiments were conducted during the rainy season. Weeding, reshaping and vine lifting were carried out in all locations. It was strongly advised that we needed to give a basal application of fertilizer (NPK 15:15:15) in Navrongo and Wa, at the rate of 400 kg/ha at four weeks after planting (WAP). Harvesting was done at 120 days after planting (DAP). For the data collection, two inner rows of each plot were harvested, leaving a plant each at the beginning and the end of row, and giving a net plot of 9m^2. Number of plants established, rating for plant vigor, foliage yield (kg/plot), biomass weight (kg/plot), weight of marketable roots (kg/plot), and total root yield (kg/plot) were measured and recorded and yield per hectare calculated. Plant establishment was observed and recorded at 4 WAP and the plant vigor at 1 month before harvest. Biomass was calculated from the total root weight per plot (kg/plot) and the total vine weight per plot (kg/plot). Harvest index (HI) was calculated from the total root weight (kg/plot) divided by the weight of biomass (kg/plot). Sweetpotato weevil damage and SPVD were rated and analyzed. For the weevil damage and the incidence of SPVD symptoms, we used the scale of 1 to 9 whereas 1 was no damage and 9 was worst. For plant vigor, we rated 1 for very poor and 9 excellent growth. The first SPVD symptoms were observed at 6-8 WAP. The second SPVD symptoms were taken 1 month before harvest. The general analysis of variance (ANOVA) and the three-way ANOVA (Anonymous, 2013) were utilized to calculate the means of each variable recorded from the trials to be statistically analyzed to draw conclusions.

3 Results

Table 2 shows the number of plants established, rating of plant vigor, foliage yield, biomass and HI. There were highly significant differences among varieties on plant establishment, plant vigor, biomass, and HI, but not for foliage yield. There were highly significant (p-value<0.001) differences among locations for all variables being observed. Moreover, a non-significant (p-value = 0.625) difference was noted from the two sources of planting material. There were also highly significant genotype by environment interactions for plant establishment at p-value<0.001 with LSD 5%=2.0 and plant vigor at p-value<0.001 with LSD 5% = 1.2 (data not shown), but interactions were not significant (p-value = 0.674) for foliage yield, biomass and HI. Interactions of variety by source of planting material were significant only for plant establishment (p-value<0.045, LSD5% =2; data not shown). In Nyankpala, plant establishment and HI were significantly(p-value = 0.001) higher than in Navrongo and Wa, when planting material was from the net tunnel (data not shown). However, from the three-way ANOVA, varieties strongly determined the meaningful results of the trials. From our observation, it was noted that Bohye and Dadanyuie established well (p-value<0.001) and had higher harvest index (p-value<0.01) at Nyankpala. For the harvest index calculation, Apomuden was superior in Wa, and Bohye in Navrongo (p-value<0.01). In contrast, the source of planting material from the open field as defined as "apparently" healthy material was interestingly found to have a better result, in some cases throughout our trials. For instances, Dadanyuie variety in Wa and Navrongo, Bohye in Wa, and Ligri in Navrongo had better HI from the open field source than from the net tunnel (p-value<0.001; data not shown).

Table 3 shows the storage root yield (t/ha), weight of marketable storage roots (t/ha), rating of the first and second observation SPVD and rating for weevil damage throughout the trials in 3 sites and two sources of planting materials. A highly significant difference was found among varieties on storage root yield, weight of marketable

Table 2: Number of plant establishment, rating of plant vigor, foliage yield, biomass and harvest index (HI)

Item	Number of established plants	Rating of plant vigor	Foliage yield (kg/plot)	Biomass (kg/plot)	Harvest Index (HI)
Variety					
Apomuden (orange flesh)	31	7.1	8.9	22.0	0.6
Bohye (light orange flesh)	32	5.8	7.4	16.0	0.5
Dadanyuie (yellow flesh)	28	6.0	8.3	15.1	0.5
Ligri (cream flesh)	32	6.8	8.5	22.4	0.6
p-value	**	**	Ns	**	**
LSD5%	1	0.7	-	4.0	0.05
Location					
Navrongo	31	7.0	12.1	26.2	0.5
Nyankpala	30	5.3	7.4	16.3	0.5
Wa	32	7.0	5.3	14.0	0.6
p-value	**	**	**	**	**
LSD5%	2	0.6	2.0	3.4	0.05
Source of Planting Material					
Net tunnel	31	6.5	8.6	19.6	0.6
Open field	31	6.4	7.9	18.1	0.6
p-value	ns	ns	ns	ns	ns
LSD	-	-	-	-	-
Grand mean	31	6.4	8.3	18.9	0.6
cv%	6.6	15.8	41.4	31.4	14.0

**high significance: p-value < 0.01 at LSD 5%; ns = non-significance

Table 3: Storage root yield (t/ha), weight of marketable roots (t/ha), rating of the first and second observation for SPVD and rating for weevil damage

Item	Root yield (t/ha)	Weight of marketable roots (t/ha)	1st SPVD rating (1 to 9)	2nd SPVD rating (1 to 9)	Rating of weevil damage (1 to 9)
Variety					
Apomuden (orange flesh)	14.5	7.4	1.2	1.2	2.9
Bohye (light orange flesh)	9.5	6.8	2.6	3.2	1.8
Dadanyuie (yellow flesh)	7.6	5.5	2.4	2.2	2.1
Ligri (cream)	15.4	13.1	1.7	1.7	1.4
p-value	**	**	**	**	**
LSD5%	2.4	2.4	0.4	0.5	0.4
Location					
Navrongo	15.7	10.4	1.9	1.8	2.9
Nyankpala	9.9	7.4	2.0	2.3	1.1
Wa	9.7	6.7	2.0	2.1	2.2
p-value	**	**	Ns	(*)	**
LSD5%; (LSD10%)	2.4	2.1	-	(0.3)	0.3
Source of Planting Material					
Net tunnel	12.2	8.4	1.5	1.7	2.1
Open field	11.3	7.9	2.5	2.4	2.1
p-value	ns	ns	**	**	ns
LSD5%	-	-	0.3	0.4	-
Grand Mean	11.8	8.2	2.0	2.1	2.1
cv%	30.9	42.6	28.7	37.3	27.2

**high significance: p-value<0.01; *significance: p-value<0.05, both at LSD 5%; (*) significance at p-value<0.1 with LSD10% written inside of the brackets; ns = non-significance storage roots, the first and second observation of the SPVD and rating of the damage by sweetpotato weevils (Cylas spp). A highly significant (p-value = 0.001) difference was found in among locations on storage root yield, weight of marketable storage roots and rating of weevil damage. Non-significance (p-value = 0.743) was found on the first observation of SPVD. However, the second observation of this disease showed no statistically significant differences among experiment variance at p<0.05, but differences of virus incidence was stated with 10% probability (p<0.1). Non-significance was noted between the two sources of planting material, i.e. net tunnel versus open field, on the total yield of the storage roots, weight of marketable storage roots and weevil damage. Nonetheless, a high significance (p-value<0.001) was observed between the two sources of planting materials (net tunnel vs open field) for both observations on the SPVD.

A highly significant difference was found among varieties across locations on the total root yield (p-value<0.001), weight of marketable storage roots (p-value = 0.01), SPVD at the second observation (p-value = 0.003), and weevil damage (p-value<0.001). In the first observation of SPVD symptoms, a non-significance was recorded among varieties across locations (data not shown). With respect to the two sources of planting material (net tunnel vs open field), there were no significant differences among varieties on total yield of the storage roots (p-value = 0.305), weight of marketable storage roots (p-value = 0.547), the second observation of SPVD symptoms (p-value = 0.278) or damage caused by weevils, except for first observation of SPVD symptoms at p-value = 0.001 (LSD5% = 0.5; data not shown). It was recorded that Bohye, Dadanyuie and Ligri varieties have shown their superiority if the sources of their planting material came from the net tunnel. Meanwhile, Apomuden did not show any differences whether it was collected from the net tunnel or from the open field.

4 Discussion

The statistical analyses were also done using three-way analysis of variance. The interactions between the four varieties across the three locations and two sources of planting material were investigated. No significant interaction was found in the total root yield (p-value = 0.320), weight of marketable storage roots (p-value = 0.456), and weevil damage (p-value = 0.370). Although in Table 3, it shows that Navrongo had weevil damage significantly higher compared to other sites if we considered that the locations were the main factor in the analysis of variance. Interestingly, in this case, we did not have any serious problem with weevil damage on the varieties being investigated. Possibly, we have used the clean planting material for this trial, so that we could maintain the clean condition of the planting material. Lastly, Nyankpala was recorded to have the least weevil damage. The sweetpotato Weevil (Cylas spp.) can cause losses of 60 to 100% due to quality loss in susceptible varieties and with delayed harvesting (Sorensen 2009).

From Table 3, it was noted that among varieties, there were highly significant differences on the SPVD symptoms at the first (LSD5% = 0.4) and second (LSD5% = 0.5) observation at p-value<0.01. Furthermore, no significant difference (p-value = 0.38) on the SPVD symptoms among locations at the first observation was observed but the symptoms at the second observation on the SPVD incidence were clearly appearent and this was significantly noted and importantly to be considered (written in vague manner, needs to be re written), although, it was only at p-value of 0.1 and LSD10% of 1.1 (Snedecor and Cochran 1980; Morad 1989; Moore and McCabe 1999). It is shown from the results that the SPVD incidence were clearly depended on varieties and the sources from where the planting materials were taken. The Bohye, Dadanyuie and Ligri plants continued having less SPVD symptoms across the three sites, i.e. Navrongo, Nyankpala and Wa if the source of planting material came from net tunnel. It is likely that Wa and Nyankpala were noted to have a high SPVD pressure compared to Navrongo (Table 3). Nonetheless, a non-significant (p-value = 0.38) difference on SPVD symptoms was recorded in Apomuden. Furthermore, this variety has shown a SPVD symptomless in all the three sites. There was non-significant (p-value = 0.38) difference on the SPVD incidence from Apomuden irrespective of the case whether the planting material was from the net tunnel or from the open field. This result could be from the “negative selection” which was intensively done on this variety. Hence, this variety has steadily been showing less symptoms for SPVD. This finding has confirmed the early research finding done in Malawi in 2012 (Abidin 2012). This result is also consistent with the fact that the Apomuden was not from pathogen-tested sources, so in this case, there was no clear advantage to multiplying planting material in the net tunnel, where as in the case of the pathogen-tested varieties, there was a clear advantage. Nevertheless, the lack of virus-free or clean planting material is regarded as a major constraint. Most of the local landraces and introduced materials are degenerated because of the sweetpotato virus disease. In fact, a variety can be disappeared from the farmers’ collections. For instance, an old orange-fleshed sweetpotato variety in

Malawi, Kamchiputu, cannot be found anywhere in this country (B. Mtimuni, personal communication).

It is also revealed that by improving the fertility of the soil, i.e. Navrongo, this can give high yield as seen in Table 3. There is a need to improve more soil fertility in Wa as seen on its average yield, it is almost like the yield recorded in Nyankpala where we did not utilize any fertilizers in this site. The health status of plants is very important to be maintained and it is considered through its good agricultural practices and using clean planting material. Several references indicate that a yield gain of 30–50% could be obtained through healthy planting material (Fuglie et al. 1999). In our trial, healthy planting material selected against SPVD symptoms, (for example employing the negative selection method intensively at the farmers' fields), effectively maintained the health status of the sweetpotato in the field in the absence of pathogen-tested planting material. However, the advantage of pathogen-tested planting material multiplied in net tunnels was also demonstrated through reduced virus symptoms in the cases of Ligri, Bohye and Dadanyuie.

The results from this research have indicated that "apparently" healthy planting material was as effective as pathogen-tested planting material on the assumption that an intensive Negative Selection method was taken on. Net tunnels may have a distinct advantage for maintaining and multiplying planting material to produce healthy sweetpotato crops. It is suggested that for SPVD, net tunnel source is better than open field. For weevils, net tunnel was also significantly better than open field, but this was also dependent on locality. Nonetheless, work in Cuba indicates that about 10-20% increase in yield could be expected through a better control of sweetpotato weevil (Lagnaoui et al. 2000).

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