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Staking Options for Sustainable Yam Production in Ghana

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Abstract

The study evaluated staking options to address the problem of deforestation for sustainable yam production in the Forest and Forest-Savannah Transition zones of Ghana. A split-plot design with three yam varieties (Dente, Water Yam and TDR95/19177 line) and three staking options (No staking, Vertical staking and Trellis with 50% and 30% number of vertical stakes for 2012 and 2013 respectively) as main plots and subplots respectively were used. Results revealed a significant ($P \leq 0.05$) interaction between yam variety and staking options on yam tuber yields in both locations and years. While water yam had similar tuber yields under all staking options, Dente and TDR95/19177 under no staking had significant yield reductions ranging from 37 to 65% compared to the other staking options. The observed yield reduction under no staking of Dente and TDR95/19177 could be attributed to higher incidence of yam mosaic virus leading to significantly lower fresh leaf biomass production. Reducing the number of stakes in trellis to as low as 30% of the vertical/optimum staking option did not result in a significant reduction in tuber yields for TDR95/19177 and Water yam. The economic analysis revealed that it is more profitable to produce water yam and TDR95/19177 under no staking and trellis (50% and 30% number of optimum staking) respectively in both locations. The results suggest trellis/minimum staking can be used to minimize the use of stakes, yam mosaic virus disease infection and for sustainable yam production in the face of climate change.

Keywords: climate change, deforestation, trellis staking, yam

1. Introduction

Yam is an important staple food crop and currently a major non-traditional export crop in Ghana. It is one of the two major root crops produced and consumed in Ghana and West Africa. For more than a decade, yam production and export in Ghana has ranked third in the world and first in Africa and contributes about 16% to the National Agricultural Gross Domestic Product (FAOSTAT, 2012). In Ghana, yam is mostly produced in the Forest-Savanna Transition and the Guinea Savanna zones. In the Forest-Savanna Transition zone, where trees and shrubs are not scarce as compared to the Guinea Savannah, farmers during land preparation leave selected trees and shrubs as stakes. Although most of the trees die upon burning, they are still used as stakes (Wholey & Haynes, 1971; Asante, 1996). In the Guinea Savannah where, stakes are scarce and difficult to obtain, farmers are not able to provide support for their yams, thereby affecting yields (Asante, 1996). However, with the increase in population and pressure on the limited land resources, farmers are compelled to cultivate on the same piece of land year after year. This has resulted in scarcity of stakes for yam production even in the Forest-Savannah zones (Akwag et al., 2000; EPA 2003; Ennin et al., 2014). Farmers would therefore search and use any available trees and shrubs as stakes to support their yam production thereby contributing significantly to deforestation. To address this major constraint of staking on yam production, any technique that would bring about a drastic reduction in the number of stakes used per hectare without a correspondent reduction in yields would be a welcome relief for farmers and for large-scale production for both the local and the export market. The objective of the study was to evaluate staking options (optimum number of stakes, 30% and 50% of optimum stakes) to suggest alternatives for sustainable yam production. This is to address the problem of scarcity of stakes and deforestation associated with yam production in Ghana.

2. Materials and Method

The study was conducted at Fumesua and Ejura in the Forest and Forest-Savanna Transition agro-ecological zones of Ghana, respectively in 2012 with 50% number stakes used in vertical staking and in 2013 with 30%

number of stakes used in vertical staking. The experimental design was a split-plot with three replications. Yam varieties, (Dente, (white yam), Matches (water yam) and TDR95/19177 (a promising white yam line with a potential for high yields under no staking, (Otoo et al., 2008)) as the main plot treatments and staking options (Vertical staking, Trellis staking (50% or 30% number of stakes used in vertical staking) and No staking) as sub plot treatments. Poultry manure was applied at 3 t/ha on the fields before ploughing and harrowing. Yam seeds were planted on ridges of 40-45 cm height. Each plot had an area of 144 m^2 with ten ridges and 1.2 m spacing between them. Yams were planted at 1.2 m between them on each ridge. Yam mini setts of about 350 g were treated with Dursban (Chlorpyrifos at 80 ml) an insecticide and Mancozeb , a fungicide (Dithiocarbamate 80%; 120 g) in 15 l of water before planting at the onset of the rains (March) 2012 and 2013. Chemical fertilizer 22.5-22.5-30 N-P_2O_5-K_2O kg/ha were applied 11-12 weeks after planting (Bulking stage). The three yam varieties under the different staking options were also evaluated for the incidence and severity of yam mosaic virus. The disease assessment was done at five months after planting (MAP) at Fumesua and six months after planting (MAP) at Ejura in 2012 and 2013. Disease severity was done by visual scoring as described by Migouna et al. (2001) and Odu et al. (2004) using a scale of 1-5 where 1 represented apparently no symptoms, 2 – mild symptoms, 3 – moderately severe symptoms, 4 – severe symptoms and 5 – very severe symptoms. Data collected for all the studies were subjected to analysis of variance at 5% significant level using the Statistical Analysis Software (SAS, 2007).

Table 1. Agro-ecological characteristics of the site

Characteristics	Location	
	Fumesua (6^o 41' N, 1^o 28' W)	Ejura (7^o 23' N, 1^{o}21' W)
Agro-ecological zone	Humid Forest	Forest-Savannah Transition
Soil type	Ferric Acrisol; Asuansi series upper top soil consisted of 5cm greyish brown sandy loam topsoil of dark brown gritty clay loam	Ferric Lixisol; Ejura series with 20-30cm thick top layer of loam soils. Soils are dark brown to brown fine sandy loam
Temperature (Min-Max. ^{o}C) 2010-2013	21-31	21-34
Wet season	Bimodal rainfall pattern	Bimodal rainfall pattern
Major	March –mid August	March –mid- August
Minor	Sept-Nov; peak in Oct	September- Nov; peak in Oct
Total annual rainfall (mm)	2012 (1028 mm) 2013 (1226 mm)	2012 (1114 mm)2013 (1210 mm)

Adopted from Adu and Asiamah, 1992.

3. Results

The staking options significantly ($P \leq 0.05$) affected the fresh leaf biomass and tuber yields of yam varieties at both Fumesua and Ejura in both years (Figures 1a, 1b, 2a, 2b, 3a & 3b). Generally, the total yields were significantly ($P \leq 0.05$) higher for the optimum staking option (vertical staking) of the yam varieties as compared to the non-staking option (Figures 1a, 1b, 2a & 2b) in both locations except water yam. However, the differences in yields for the vertical and trellis (50% and 70% less stakes) staking options were not significantly different for TDR95/19771 as compared to Dente where significant differences were observed in the vertical and trellis staking options in both locations (Figures 1a, 1b, 2a & 2b). The percentage yield reduction of the no staking option with reference to vertical staking was more pronounced in Dente (48-64%) followed by TDR95/19771 (37-45%) with water yam having the least yield reduction (6-10%) for both locations and years (Figures 1a,1b, 2a & 2b). Generally, water yam produced more fresh leaf and vine biomass followed by TDR95/19771 and Dente in both locations (Figures 3a & 3b). The yield reduction was not significantly different for TDR95/19771 with vertical and trellis staking options for both locations and years (Figures 1a, 1b, 2a and 2b).

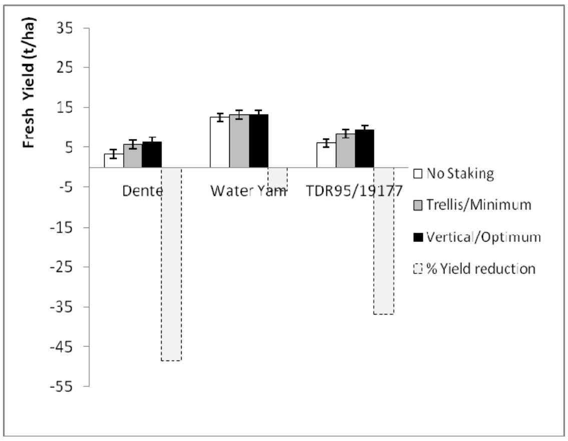

Figure 1a. Effect of staking options on tuber yield of yam, Fumesua (2012)

NB: Trellis/Minimum staking option had 50% number of vertical staking option

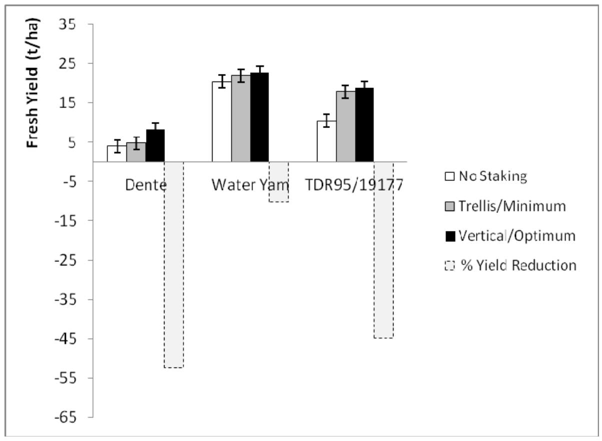

Figure 1b. Effect of staking options on tuber yield of yam, Ejura (2012)

NB: Trellis/Minimum staking option had 50% number of vertical staking option

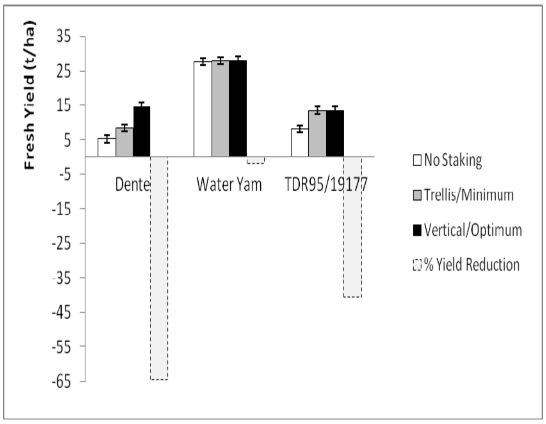

Figure 2a. Effect of staking options on tuber yield of yam, Fumesua (2013)

NB: Trellis/Minimum staking option had 30% number of vertical staking option

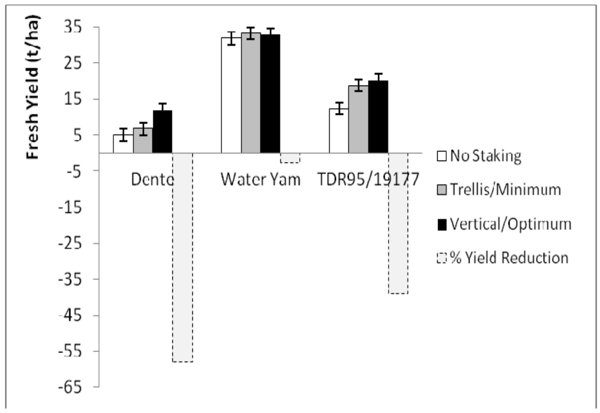

Figure 2b. Effect of staking options on tuber yield of yam, Ejura (2013)

NB: Trellis/Minimum staking option had 30% number of vertical staking option

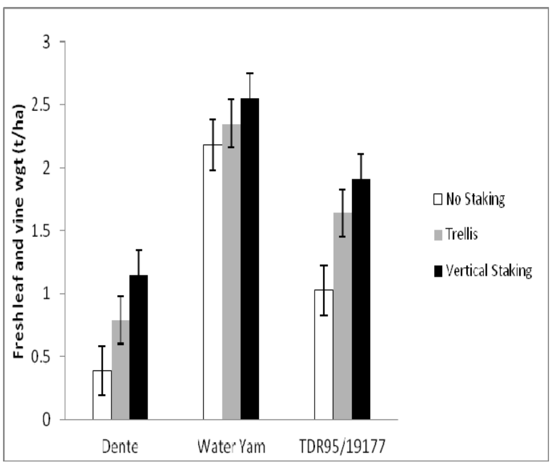

Figure 3a. Effect of staking options on fresh leaf biomass of yam varieties, Fumesua

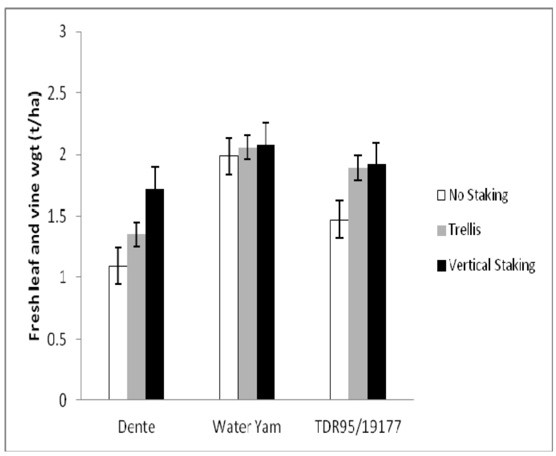

Figure 3b. Effect of staking options on fresh leaf biomass of yam varieties, Ejura

The staking options had similar effects on weed suppression, however variety significantly ($P \leq 0.05$) affected weed suppression with TDR95/19177 suppressing weeds 34% and 32% more than Dente and water yam respectively (Figure 4). Generally, virus incidence and severity on the three varieties were higher at Ejura than Fumesua in both 2012 and 2013. Also, virus incidence and severity were higher in 2012 than 2013 in both locations. Virus incidence and severity were low on water yam irrespective of the staking options for both years and locations. Dente and TDR95/1977 subjected to no staking had significantly ($P \leq 0.05$) higher percentage virus incidence and severity as compared to the other staking options (vertical and trellis) in both locations (Tables 2). However, values for virus incidence and severity observed for Dente and TDR95/1977 subjected to vertical and trellis staking in both locations were quite similar (Table 2).

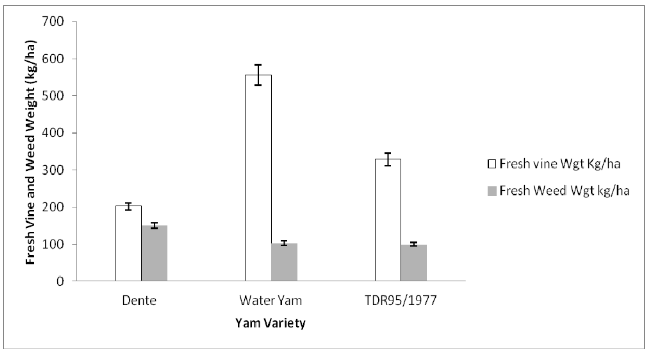

Figure 4. Biomass and weed suppression of three yam varieties (Fumesua, 2013)

Table 2. Effect of yam varieties subjected to different staking options on incidence and severity of mosaic virus, 5-6 months after planting at Fumesua and Ejura in 2012 and 2013

2012 Trellis/Minimum staking option with 50% number of vertical/optimum staking option																
Location	Fumesua						Mean		Ejura						Mean	
Yam variety	Dente		Water yam		TDR95/19177				Dente		Water yam		TDR95/19177			
Mosaic Virus	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE
No staking	42.3	2.8	3.7	1.7	75.7	2.4	40.6	2.3	95.3	3.3	10	1.5	74	3.7	59.8	2.8
Trellis	31.7	2.3	1.7	1	48	2.1	27.1	1.8	62	3.2	5	1.1	59	3	42	2.4
Vertical	30	2.3	0	1	47.7	2	25.9	1.8	47	3	0	1	57	2.7	34.7	2.2
Mean	34.7	2.5	1.8	1.2	57.1	2.2	31.2	2	68	3.2	5	1.2	63.3	3.1	45.5	2.5
SED	1.72	0.24	1.72	0.24	1.72	0.24	1.72	0.24	2.42	0.22	2.42	0.22	2.42	0.22	2.42	0.22
2013 Trellis/Minimum staking option had 30% number of vertical staking option																
Location	Fumesua						Mean		Ejura						Mean	
Yam Variety	Dente		Water yam		TDR95/19177				Dente		Water yam		TDR95/19177			
Mosaic Virus	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE	%IN	SE
No staking	15.3	2.8	0	1	21.3	1.8	36.6	1.9	63.3	2.5	3.4	1.3	36	3.7	34.2	2.5
Trellis	9.1	1.8	0	1	5.3	1.1	4.8	1.3	30	2.2	1	1	21	2	17.3	1.7
Vertical	5.3	1.7	0	1	3.3	1	2.9	1.2	27	2	1	1	21	2	16.3	1.7
Mean	10	2.1	0	1	10	1.3	14.8	4.4	40.1	2.2	1.8	1.1	26	2.6	22.6	2
SED	1.17	0.18	0	0.2	1.17	0.18	1.17	0.18	2.13	0.22	2.13	0.22	2.13	0.22	2.13	0.22

%IN- Percentage Incidence; SE- Severity Score (1-5); 1- apparently no symptoms, 2- mild symptoms, 3- moderately severe symptoms, 4- severe symptoms and 5- very severe symptoms.

Table 3 presents the partial budgeting and cost benefit analysis of three varieties of yams under vertical staking, trellis/reduced staking and no staking options in the forest (Fumesua) and transition (Ejura) zones. Results from the 50% less stakes study in the 1st year (2012), revealed that water yam under no staking resulted in higher benefit-cost-ratio at both Fumesua (2.3:1) and Ejura (4.2:1) compared with trellis (50% reduced stakes) and vertical staking options that gave benefit-cost-ratio of 1.9:1; 3.9:1 and 1.4:1; 3.5:1 in Fumesua and Ejura, respectively (Table 3). For TDR95/19177 the highest benefit-cost-ratio was recorded for the trellis option in Ejura (3.4:1) whiles Fumesua had 1:1. However, in Fumesua and Ejura, the vertical staking of Dente had the highest benefit-cost-ratio 0.5:1 and 1:1, respectively (Table 3). When the trellis option had 30% number stakes used in vertical staking in the 2nd year (2013), the results followed similar trend. Non-staked Water yam had the highest benefit-cost-ratio of 6.5:1 in both Fumesua and Ejura, respectively followed by TDR95/19177 on trellis with benefit-cost-ratio of 2.8:1 and 3.3:1 in Fumesua and Ejura respectively (Table 3). The vertical staking of Dente recorded 2.8:1 and 3.4:1 benefit-cost-ratio in Fumesua and Ejura (Table 3).

Table 3. Partial budget and cost benefit analysis of three yam varieties under Vertical, Trellis and no Staking options at Fumesua and Ejura

	2012 Trellis/Minimum staking option with 50% number of vertical staking option																	
Location	Fumesua									Ejura								
Yam Variety	Dente			Water yam			TDR95/19177			Dente			Water Yam			TDR95/19177		
Staking Option	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS
Average yields(kg/ha)	6400	5500	3300	12500	13200	13300	9500	8800	6000	8400	4800	4000	22800	22000	20500	19000	18000	10500
Adjusted yield*	5760	4950	2970	11250	11880	11970	8550	7920	5400	7560	4320	3600	20520	19800	18450	17100	16200	9450
Gross benefit($/ha)	1555	1337	802	1913	2020	2035	1881	1742	1188	2041	1166	972	3488	3366	3137	3762	3564	2079
Cost of Poultry manure($/ha)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Labour cost poultry manure appl. ($/ha)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Chemical Fertilizer($)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Labour cost for application of Fert.($/ha)	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
land clearing($/ha)	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Construction of ridges (S/ha)	50	50	50	50	50	50	50	50	50	33	33	33	33	33	33	33	33	33
Cost of seed yam($)	383	383	383	127	127	127	255	255	255	383	383	383	127	127	127	255	255	255
Labour cost of planting($/ha)	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Cost of stakes($/ha)	83	42	0	83	42	0	83	42	0	83	42	0	83	42	0	83	42	0
Labour cost of staking($/ha)	93	47	0	93	47	0	93	47	0	93	47	0	93	47	0	93	47	0
Cost of weeding and reshaping($/ha)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Harvesting cost($/ha)	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Total cost that vary	1048	960	871	791	703	615	920	831	743	1031	943	855	775	686	598	903	815	726
Net benefit	507	377	-69	1121	1317	1420	962	911	445	1010	224	118	2714	2680	2539	2859	2750	1353
Benefit cost/Ratio	**0.5**	**0.4**	**-0.1**	**1.4**	**1.9**	**2.3**	**1**	**1.1**	**0.6**	**1**	**0.2**	**0.1**	**3.5**	**3.9**	**4.2**	**3.2**	**3.4**	**1.9**
	2013 Trellis/Minimum staking option with 30% number of vertical staking option																	
Location	Fumesua									Ejura								
Yam Variety	Dente			Water yam			TDR95/19177			Dente			Water Yam			TDR95/19177		
Staking Option	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS	Vet	Trel	NS
Average yields(kg/ha)	14700	8400	5300	28100	28000	27600	13600	13500	8100	16700	10400	7300	28100	28000	27700	15600	15500	10100
Adjusted yield*	13230	7560	4770	25290	25200	24840	12240	12150	7290	15030	9360	6570	25290	25200	24930	14040	13950	9090
Gross benefit($/ha)	4366	2495	1574	5058	5040	4968	3305	3281	1968	4960	3089	2168	5058	5040	4968	3791	3767	2454
Cost of Poultry manure($/ha)	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Labour cost poultry manure appl. ($/ha)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Chemical Fertilizer($)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Labour cost for application of Fert.($/ha)	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Land clearing($/ha)	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Construction of ridges ($/ha)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Cost of seed yam($)	433	433	433	133	133	133	283	283	283	433	433	433	133	133	133	283	283	283
Labour cost of planting(S/ha)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Cost of stakes($/ha)	90	27	0	90	27	0	90	27	0	90	27	0	90	27	0	90	27	0
Labour cost of staking($/ha)	93	30	0	93	30	0	93	30	0	93	30	0	93	30	0	93	30	0
Cost of weeding and reshaping($/ha)	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Harvesting cost($/ha)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Total cost that vary	1143	1017	960	843	717	660	993	867	810	1143	1017	960	843	717	660	993	867	810
Net benefit	3223	1478	614	4215	4323	4308	2311	2414	1158	3817	2072	1208	4215	4323	4308	2797	2900	1644
Benefit cost/Ratio	**2.8**	**1.5**	**0.6**	**5**	**6**	**6.5**	**2.3**	**2.8**	**1.4**	**3.4**	**2.1**	**1.3**	**5**	**6**	**6.5**	**2.8**	**3.3**	**2**

NB:* Average yield adjusted 10%; Farm gate price per kg of Dente in 2012 =us$ 0.27; Farm gate price per kg of water yam in 2012 =US$ 0.17; Farm gate price per kg of TDR95/19177 in 2012 is assumed to be average for Dente and Water yam = us$ 0.22; NS, Trel and Vet: No staking, Trellis/minimum and Vertical staking options respectively. Trellis/minimum staking had 50% the number of stakes used in vertical staking. NB:* Average yield adjusted 10%; Farm gate price per kg of Dente in 2013 =us$ 1.33; Farm gate price per kg of water yam in 2013 =us$ 0.22; Farm gate price per kg of TDR95/19177 in 2013 is assumed to be average for Dente and Water yam =us$ 0.27; NS, Trel and Vet; No staking, Trellis/minimum and Vertical staking options respectively. Trellis/minimum staking had 30% the number of stakes used in vertical staking.

4. Discussion

Generally, the average tuber yields were higher in 2013 (17.8 t/ha) as compared to 2012 (11.6 t/ha) (Figures 1a, 1b, 2a and 2b). This might be due to the more total rainfall and lower yam mosaic virus infection in 2013 as compared to 2012. The results suggested that the influence of staking option on leaf biomass, disease infection and tuber yields is more dependent on the yam variety and therefore breeding and agronomic techniques can be used to at least reduce the number of stakes needed in production. In both locations, no significant differences were observed in the yields and virus infection of water yam irrespective of the staking option (Figures 1a, 1b, 2a & 2b). This might be due to the vigorous growth and biomass production of water yam as compared to Dente and TDR95/19771 (Figures 3a & 3b), making the staking option have little effect on sunlight interception abilities of the plant (Diby et al., 2011; Asante, 1996). Diby et al. (2011) observed in a study that the higher leaf area index of water yam (*Dioscorea alata*) as compared to Dente/white yam (*Dioscorea rutundata*), served as advantage to capture sunlight to produce more yields. In addition, virus incidence and severity on water yam was relatively low as compared to the other two varieties irrespective of the staking options used (Table 2). Thus, virus infection had little effect on water yam growth and yields. With these observations, farmers who are into water yam production can be encouraged to grow them without staking to take away the labour associated with staking.

The significant ($P \leq 0.05$) influence of staking options on the biomass, disease infection and tuber yields of Dente and TDR95/19177 yam varieties irrespective of the location indicates the crucial role staking plays in the Rotundata family. Yam mosaic virus is reported to cause a decline in yields of yam especially the Rotundata species (IITA, 1981; Amusa et al., 2003). The significantly ($P \leq 0.05$) higher yam mosaic virus infection of the non-staked yam compared to the other staking options of the two white yam varieties used in the study (Dente and TDR95/19177) (Table 2) might have contributed to the low leaf and vine production (Figures 3a and 3b). This observation might have led to the significantly lower tuber yields of the non-staked options compared to the other staking options for Dente and TDR95/19177 in both locations and years (Figures 1a, 1b, 2a and 2b).

However, in most cases there were no significant differences in the virus infection and tuber yield of TDR 95/19177 under trellis (both 50% and 30% number of stakes) and vertical staking options for both locations (Figures 1a, 1b, 2a and 2b). This suggests, the production of TDR95/19177 can be sustained at least under minimal staking (30-50% stakes) condition as compared to Dente, which seems would need optimum/vertical staking to obtain optimum yield. From the study, it seems breeding for Rotundata lines tolerant to virus disease and ability to produce high biomass under no staking would be the way forward in achieving sustainable yam production without staking.

The benefit cost ratio of the economic analysis has generally confirmed that it is more profitable to produce water yam and TDR95/19177 under no staking and trellis (30% and 50% number of optimum staking) respectively in both locations (Table 3). This is evidenced in a benefit cost ratio of 1.0:1 and 3.4:1 for TDR95/19177 in Fumesua and Ejura respectively (Table 3). Thus, a farmer will accrue US$ 1.00 plus an additional US$ 2.40 if he/she invested US$ 1.00/ha cultivating TDR95/19177 variety using trellis/reduced stakes at Ejura. The farmer will still have better benefits at Fumesua if he/she opted to plant TDR95/19177 under trellis/reduced staking. If he/she invested US$ 1.00 he /she would get back the US$ 1.00 invested and additional US$ 0.10 (Table 3). Reducing the number of stakes by 70% increases the farmers' profit further, a benefit cost ratio of 2.8:1 and 3.3:1 at Fumesua and Ejura (Table 3). This implies when a farmer invest US$ 1.00 in cultivating TDR95/19177 variety using trellis at Fumesua he/she would accrue US$ 1.00 and additional profit of US$ 1.80. However if a similar investment is done at Ejura, the farmer would accrue a profit of US$ 2.30 and the US$ 1.00 invested. The study has demonstrated that with the appropriate selection and breeding of yam variety, there is hope of at least sustaining yam production on 30-50% number of stakes compared with the current optimum staking practice, if not under no staking. This would reduce the drudgery associated with the search for stakes and pressure on the forest to address the problem of deforestation.

5. Conclusions

Results from the study have revealed, it is more profitable to produce water yam under no staking. The number of stakes currently being used in yam production can be reduced by 50-70% to sustain the yield of TDR95/19177. No staking of TDR95/19177 yam line resulted in about 37-45% yield reduction in both locations, thus further breeding would be required in developing varieties with high yields and virus disease resistance/tolerance under no staking. Promotion of water yam production under no staking option would require intensive education of farmers using demonstration plots. Further studies would be needed in the estimation and quantification of environmental savings/service associated with the use of the no staking option as against the use of other staking options in yam production. It is anticipated, that the sum of the environmental savings and the yield of the no staking option would merit its use. The study has suggested significant reduction (50-70%) in the number of stakes used in yam production is possible. This would greatly reduce the contribution of yam production to deforestation in the face of climate change.

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