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Farmer-based dynamics in tissue culture banana technology adoption: a socio-economic perspective among small holder farmers in Uganda

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The rates at which tissue-culture banana technology at smallholder farmer level in Uganda are adopted have reduced since the late 1990s. The study assessed the socio-economic factors influencing adoption of this technology by smallholder farmers. A survey on 280 smallholder farmers sampled from Western Uganda was conducted and responses were subjected to principal component analyses. There are evidences of very low levels of adoption of the tissue culture banana technology. There is a mix between households that completely reject tissue culture banana technology, and others growing diminutive amounts of tissue culture bananas alongside non-tissue culture banana varieties. The scale of production and productivity of non-tissue banana varieties significantly exceeds that of tissue culture bananas (83%: 17%). While expected yield from a banana production technology is a precursor to its adoption, demographic and management characteristics shape the practices that enhance the yield of tissue culture banana technology ($p \leq 0.05$) and subsequent decision to adopt or reject tissue culture banana technology. A systems-wide approach is needed to develop mechanisms that would stimulate smallholder farmers to adopt the technology in order to realize the immense potential of tissue-culture banana technology.

Key words: tissue culture banana; adoption, rejection, socio-economic, banana yield, a systems wide approach.

INTRODUCTION

Banana (*Musa* spp.) is one of the earliest crop plants to have been domesticated, (Kamira et al. 2016) originally planted, and adapted to the humid tropics and the broad subtropical climatic conditions (Murielle et al., 2015). They provide a staple food for millions of people of diverse ethnic groups in Africa (Surendar et al., 2013; Ochola et al., 2015), and consumed in various forms (Anyasi et al., 2013). The banana consumption methods have not only evolved but have also been refined by humans over time (IFAD, 2012). They are eaten raw, cooked, baked, steamed or fermented (Ravi, 2013). In many places, the whole fruit plant is exploited with uses drawn from leaves, pseudo stem, medicinally rich plant sap or fiber. Other than their edible fruit, the bananas are grown for specific purposes that have become interwoven with the social cultural and livelihood benefits of the human society (Ravi, 2013). Whereas, it is quite true that bananas are versatile, the present discussions have often times more than not fallen short of addressing the socio economic dynamics within smallholder farmers affecting the adoption of the new technologies that come along with the development of this fruit crop. Some studies generally tag adoption of the new banana technologies to the levels of diversity of cultivars on the market, (Changadeya et al., 2012), and the extent to which the technology addresses smallholder farmers' agronomical problems (Changadeya et al., 2012; Langat et al., 2013; Husen et al., 2017), as well as how the new technologies lead to increased production and profit (Dube 2017). Such factors inform farmers' cultivar predilections and socio-economic needs to be met when choice from the available diversity is made.

The smallholder farmers are the major implementers of the developed banana production technologies and also co-experimenters in the development of agricultural technology (Bongers et al., 2012), and live by the results of research. These farmers' knowledge allows for development of farming systems and procedures essential in accepting banana cultivars that give good yield. The cultivars usually adopted are those adapted to the social and ecological circumstances within which the smallholders live and operate (Mwangi and Kariuki, 2015). Recent trends in increased suburbanization (UBOS, 2010) and a significant drop in the incomes of traditional cash crops in Uganda (MAAIF, 2011) gradually led to the commercialization of banana production in the country (UBOS, 2016).

The tissue culture banana (TCB) is a biotechnological agricultural improvement based on the ability of many plant species to regenerate a whole plant from a single shoot tip; developed widely for use in commercial banana production (Wandui et al., 2013). The technology was extended to the small holder farmers as a package that included disease and pest free plantlets, information on crop husbandry, and post-harvest handling practices (Nguthi, 2007). The introduction of tissue culture banana technologies to smallholder farmers was primarily aimed at meeting the commercial demands in banana production, (Mbaka et al., 2008), draw smallholder farmers out of poverty (IFAD, 2009), and enhance food security across the East African countries (Kalyebara et al., 2002; IFAD, 2009; MAAIF, 2011; Godfrey et al., 2014; Alex et al., 2016). However, the acceptability of the technology by smallholder farmers has continued to wobble. For instance, by 2003, according to Akankwasa et al. (2016), two hundred and fifty mother gardens had been established and 40,000 tissue cultured plantlets distributed in Uganda; however, results of the same study show that about 6% of the farmers are willing to select varieties that have gone through the tissue culture production process . Many of the smallholder farmers chose local types as their most preferred varieties (Mwangi and Kariuki 2015; Akankwasa et al., 2016). Smallholder farmers are able to compare production potentials of tissue culture originated banana against the land races. Whereas the former are preferred on production potentials; they are still regarded as inferior with respect to consumption characteristics. In the choice of planting materials, the smallholder farmers tend to ignore the current tissue culture technology products and remain hooked to land race banana types (AAA genomes), with Matooke and Mbidde being the most common of the land races. It is uncertain which specific socio economic factors are major players in the rejection and discontinuance of the tissue-culture banana technology. The need to concretize the factors for non-adoption and discontinuance after adoption of tissue culture banana by smallholder farmers is vital.

MATERIALS AND METHODS

Study area description

A survey was carried out in Uganda among smallholder farmers in the mid-western region comprising the districts of Mbarara, Ibanda, Kiruhura and Isingiro. The specific locations of smallholder farmers are geo-referenced. The area lies between coordinates 1° 00'N and 32° 00'E. It occupies a surface area of 241,551 km^2, of which 17% (41,025 km^2) is water mass. Only 34 % (69,000 km^2) of the land is arable. Permanent crops mainly coffee, and bananas cover 22,500 km^2 which is 33% of the total arable land. Generally, the climate is warm and humid. Altitude of 1800 masl is the main determinant of rainfall in the study area, with variations occasionally induced by topography (UCA, 2009). The rainfall patterns of the area are bimodal with a maximum annual average ranging between 800 and 1,200 mm, annually, with the rains received in March, April, October, and November (NEMA, 2016). The climate is generally tropical. The temperature is 2°C, but always high in the dry periods

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of June, and the driest month of July,

The study area was a beneficiary of *"Agricultural Productivity Enhancement Program"* (APEP) technology transfer program for Uganda 2003 to2008. This program used field demonstrations as a means to increasing banana productivity. Through the demonstration plots, some smallholder farmers were exposed to appropriate tissue-culture banana technologies that included improved banana crop management practices involving use of both organic fertilizers (e.g., manure and mulch) and inorganic fertilizers to restore soil fertility. In addition, selected farmers received planting materials including tissue-culture banana plantlets.

Study design

An explanatory mixed methods research design was followed. Quantitative data were backed up with qualitative information from focus-group discussions and interviews. A cross-sectional survey was used to obtain factors limiting smallholder farmers to adopt tissue culture banana technology. Surveys are done to obtain information relating to the respondents (Denscombe, 2010). In this particular study, the respondents are smallholder banana farmers defined under section 1.2.3. A self-administered questionnaire was used to elicit socio-economic information relating to general banana production at smallholder farm level. Through triangulation various aspects of tissue culture banana phenomena were compared. Such phenomena included among others, comparing age against preference for tissue-culture banana, household leadership and the type of banana grown. Triangulation further helped in validating and verifying the accuracy of quantitative information (Ajay and Micah, 2014).

The unit of analysis and target population

The "unit of analysis" for this study was the smallholder farmer. The study defines smallholder farmer as a farmer who has grown bananas and lived on the same land, shared banana food resources from a common source and contributed to the resource pool of the household for a period not less than fifteen years. This definition became part of the specific criteria developed to determine the purposive sample population for the study.

Resident banana farmers in the study area formed the target population. Smallholder farmers who have been in banana production for at least fifteen years were largely considered. This span of time covers the pre-tissue culture banana period to the present period of tissue culture banana technology in the study region. Key informants included agricultural extension workers and researchers. These provided extensive and reliable information required validate data provided by other respondents.

Sample size and sampling design

Before actual sample size was determined, it was necessary to determine the population size of the target population. However, for this study, the actual population of the smallholder farmers engaged in tissue culture production was not known from the start due to limited data bases available at the districts, the mosaic nature of the farmers, as well as the absence of records from the farmers themselves. Further still, tissue culture banana growing follows a fluid-miscellany character. The study employed the Hyper geometric method adopted from Wackerly et al. (2008) to estimate the unknown population The population was then estimated using the margin of error of ±0.05 as defined by Ajay and Micah (2014). A deviation higher or lower than 5% from the mean was accepted thus giving a confidence level at 95%. Standard deviation, that is, the degree of variance the study expected from the responses was 0.5. (Ajay and Micah, 2014). This figure was a safe estimate for the surveys that have not been administered. For this study, 50% was the most lenient estimation which ensured that the population size was large enough. The confidence level selected corresponds to a Z-score of 1.96; hence the estimated population size determination followed the formula.

$$N = (Z - score)^2 * SD * {(1 - SD)}/{(mE)^2}$$

Where, N is the required sample size, SD is the standard deviation = (0.5), mE is the margin of error = (0.05).

$$N = (1.96)^2 * 0.5 * {(1 - 0.5)}/{(0.05)^2}$$

(3.8416 x 0.25) / .0025
0.9604 / 0.0025
384.16
385

At a margin of error of 0.05, standard deviation of 0.5, and confidence level of 95%, the population size for the study was 385 smallholder farmers. Since the estimated study population is small, the study assumed the calculated population size to be the sample size of the survey. However, there was need to further calculate the true sample of the population in order to determine the minimum number of smallholder banana farmers that would be sufficient to have a 95% confidence interval, with a 5% margin of error in the results. Hence the finite population was determined using the formula;

$$Ts = \frac{(n \times N)}{(n + N - 1)}$$

Where, Ts = True sample of the population, n = Sample size of the study, N = Population of the sample.

$$Ts = \frac{(385 \times 385)}{(385 + 385 - 1)}$$
$$Ts = 192.75$$
$$True\ sample = 193$$

The minimum number of respondents for the survey that would achieve a CI of 95% and 5% margin of error was 193 smallholder farmers. Respondents were proportionally distributed to each of the districts in the study region, such that the maximum number of respondents for each of the four districts did not exceed 95 and did not decline below 48. The distribution was further guided by purposive sampling in three major ways. Purposive sampling placed the farmers into categories based on resource endowments, and

Table 1. Descriptive criteria for resource bequest classification of farmers in western Uganda.

Respondent category	Description characteristics
Extraordinary	High level of education (tertiary education) Land holding above 5 acres Regular contact with researchers and extension staff Recurrently used hired professional labor in banana production Have permanent and pensionable employment Have means of communication and get quick feedback
Ordinary	Young households with moderate resource base Variable land holding between 1-3 acres Limited access to credit due to lack of, or insufficient mortgage Irregularly hire in labor or provide outside labor Minimal access to researchers and extension agents
Peasant	Inadequate income to buy inputs for banana production Land holding below one acre Not regular members of social groups They are major source of labor for the first two groups Very low levels of education

Adapted from: Ayuke (2010).

ability to sufficiently grasp the issues of tissue culture banana production.

Data collection

The survey was conducted between August 2017 and January 2018 in four districts viz. Ibanda, Isingiro, Kiruhura, and Mbarara, from the western region of the country in a multi-phase data collection strategy that involved orientation, key informant interviews and focus group discussions. A structured questionnaire was administered face to face to 280 farmers to collect quantitative data on the study parameters. The face to face approach provided an opportunity for auxiliary probing into the parameters under assessment. A composite index of descriptive criteria was developed with categories including; extraordinary, ordinary, peasant categories (Table 1) to facilitate composition of focus group discussions. The classification used was not mutually exclusive, but those who fulfilled most of the criteria were assigned to a specific category.

For each district, nine farmers constituted a focus group discussion, with priority being given to the farmers who possessed knowledge and experience about banana production. Four Focus Group Discussions (FDG) were carried out with a total of 36 farmers from the four districts in the region.

Analysis of data

Data were analyzed with Statistical Package for Social Sciences software (SPSS, version 16.0; Kirkpatrick and Feeny, 2008). Statistical results were regarded significant at P values ≤0.05. Variables were classified as explanatory, and response variables. Only the explanatory variables that showed significant responses towards adoption and production of tissue culture banana were included in the analysis. The factors were isolated through principle component analysis (PCA). Principle component analysis was further used to check for multi-colinearity. Multi-colinearity can inflate the standard errors in explanatory variables, (Myers and Well, 2003), causing failure to reject the null hypothesis when the data actually support its rejection (Denscombe, 2010), and thus lead to the wrong conclusions (Akinwande et al., 2015).The variables that returned the eigenvalue of ≥1, variance inflation factor (VIF) between ≥1 and ≤10, and tolerance levels above 50% , (Akinwande et al., 2015) showed that there were no multi-colinearity symptoms and so the factors were used for further analysis.

RESULTS

Principle component analyses

The empirical estimation to test the influence of socioeconomic factors on tissue culture banana technology adoption at smallholder farm level is in this section. Principle components of the factors under study were isolated. The first two components with the highest eigenvalues (4.719) and (3.599) respectively accounted for 25.2% of the total variance of all factors (Table 2) with first and second components accounting for 14.3 and 10.9% variance, respectively. The progressive left over variances as accounted for by other component factors continually reduced to 4.02%; accounted for by the last component. This distribution gave a sense of how much alteration there was in the eigenvalues from one

Component		1	2	3	4	5	6	7	8	9	10	11
Initial Eigenvalues	Total	4.719	3.599	2.569	2.378	1.778	1.732	1.454	1.324	1.166	1.070	1.015
	% of Variance	14.300	10.907	7.786	7.205	5.388	5.247	4.405	4.013	3.534	3.243	3.076
	Cumulative %	14.300	25.206	32.992	40.197	45.585	50.832	55.237	59.250	62.784	66.027	69.103
Extraction Sums of Squared Loadings	Total	4.719	3.599	2.569	2.378	1.778	1.732	1.454	1.324	1.166	1.070	1.015
	% of Variance	14.300	10.907	7.786	7.205	5.388	5.247	4.405	4.013	3.534	3.243	3.076
	Cumulative %	14.300	25.206	32.992	40.197	45.585	50.832	55.237	59.250	62.784	66.027	69.103
Rotation Sums of Squared Loadings	Total	3.584	3.353	2.449	2.234	1.888	1.795	1.653	1.570	1.547	1.405	1.327
	% of Variance	10.860	10.160	7.422	6.769	5.721	5.438	5.010	4.758	4.688	4.257	4.020
	Cumulative %	10.860	21.020	28.443	35.212	40.933	46.371	51.380	56.138	60.826	65.084	69.103

Source: Survey data 2017.

component. The sum of all PCA canonical eigenvalues showed that the component factor loading related to the type of banana grown explained 47.2% of the total 69.1% cumulative proportion of variance among the major factors that influenced the adoption of tissue culture banana at smallholder farm level.

Components with eigenvalues ≥1 (in this case explaining less than 4.02% variance) were regarded diminutive for use in further analysis. This is because, they accounted for a non-significant variance from the original variable whose initial significance is 1. Principal components analysis redistributed the variances in the correlation matrix for the first components extracted, and so controlled multi-colinearity, The factors whose absolute values were not closer to 50%, (Kaiser 1974; Anastasiadou 1996; Vertania 2011; Newing et al., 2011) were excluded from further analysis. The 18 factors that met the Kaiser Normalization criteria were placed between components 1 and 11 (Table 3)

The component factors were rotated to reduce the number of factors on which the variables under investigation had high loadings. Management of the planting materials and labor for the value chain substantially loaded onto component 1, at 82.9 and 62.1% respectively. Type of banana grown, variety of the tissue culture banana, treatment of propagation materials, and source of planting materials substantially loaded variables onto component 2, with strength above 65% for each of the loading factor. Household management and the total size coverage by tissue culture banana loaded substantially onto component 3, at 68.2 and 76.5% respectively. Source of income was loaded at 80% onto component 4. Cost of production factor was loaded onto component 5 (66.7%), while all estimated banana bunch yield factors were substantially loaded onto component 6 (46.7, 53.1 and 69.5%).

Substantial loadings onto factor 7 include gender of the farmer (70.3%) and land tenure (57.8%). Age of the farmer was loaded onto component 9 at 53.3% substantial strength. Preference factors were substantially loaded onto component 10. Finally, land use type was heavily loaded onto component 11 with a substantial loading strength of 90.2%. Whereas more than 50% variance is explained by the first six components, and substantially would be considered for further analysis; the other component loadings after component six [gender, age, land use, land tenure, and product preferences] were retained due to their contribution to qualitative socio-economic aspects.

Survey descriptions

Explanatory factors

The largest number of participants by gender

Table 3. Rotated component matrix of factor loadings from principal component analysis.

Component	1	2	3	4	5	6	7	8	9	10	11
Gender of the farmer							0.703				
House hold management			0.682								
Age of the farmer									0.533		
Size covered by TCB			0.765								
Land tenure							0.578				
Type of banana grown		0.931									
Variety of TCB grown		0.660									
Propagation materials		0.938									
Source of the materials		0.840									
Materials Management	0.829										
Labor for the value chain	0.621										
Cost of production					0.667						
Source of income				0.800							
Product preference										0.747	
Land use											0.902
Yield of cooking banana						0.467					
Yield of beer banana						0.531					
Yield of dessert banana						0.695					

Extraction method: Principal Component Analysis0; Rotation Method: Varimax with Kaiser Normalization0; Rotation converged in 11 iterations.
Source: Survey data 2017.

were males 61.1% (n=171) versus 38.9% (n=109) females. Gender distributions cut across several age categories (Table 4).

Three forms of land tenure were considered and responses indicated that 71.4% (n=200) of the smallholder farmers operate on land inherited from their parents and benefactors, while the remaining 28.6% operated on leased land hold or freehold land tenure systems. The responses on labor for the value chain in tissue culture banana production indicate that 73.2% (n=205) rely on family labor for production while the remaining 26.8% on hired professional labor and community labor. Responses on cost of production indicated that 60% (n=168) were viewed as the factor limiting the production of tissue culture banana. Other factors include cost of planting materials (11.8% n=33), limitation by transportation costs for the materials (18.9% n=53), expenses on field hygiene (7.5% n=21), and land acquisition costs (1.8% n=5).

Another concern on socio -economic aspects manifests in household management dynamics. About 55.4% (n=155) respondents indicated that households are mainly headed by the husband although a significant number of households are headed by females (31.4% n=88). In some instances, 3.2% (n=9) of the households are headed by children, while 10% (n=28) of the households are under the charge of guardians and benefactors. For the smallholder farmers' source of income, most of the farmers 68.6% (n=192) depend on income arising from sales from subsistence produce. The remaining 31.4% depend on a number of sources; among them are gifts and donations, (11.1%, n=31), wage employment (9.3%, n=26) agricultural loans (6.1%, n=17), and permanent and pensionable employment (5.0%, n=14)

The response factors

Response factors (Table 5) indicate that 80.7% (n=226) are non-adopters of tissue culture banana production technologies. Farmers who have adopted or those willing

Table 4. Explanatory variables in the adoption of tissue culture banana by smallholder farmers.

Factor	Category	N	Percent
Gender of the farmer	Male	171	61.1
	Female	109	38.9
Age of the farmer	18-29	57	20.4
	30-49	114	40.7
	50-74	102	36.4
	75+	7	2.5
Land tenure	Land inherited from parents	200	71.4
	Leased land	36	12.9
	Free hold	44	15.7
Labor for the value chain	Hired/Professional labor	40	14.3
	Family Labor	205	73.2
	Community Labor	35	12.5
Cost of production	Costs of labor	168	60.0
	Cost of TCB planting materials	33	11.8
	Costs for Field hygiene	21	7.5
	land acquisition costs	5	1.8
	Transportation costs	53	18.9
Household management	Husband is the head	155	55.4
	Wife is the head	88	31.4
	Children are the head	9	3.2
	Guardian is the head	28	10
Farmers' source of income	Permanent/pensionable source	14	5.0
	Wage employment	26	9.3
	Sales from subsistence production	192	68.6
	Agricultural Loans	17	6.1
	Gifts and donations	31	11.1

Source: Survey data 2017.

to adopt the technology 42.1% (n=118) can only allocate less than 25% of the total land to the production of tissue culture under smallholder production. Meanwhile, 83.2% (n=233) of the smallholder farmers did not use tissue culture plantlets for establishment of new banana plantations or for replacement of the damaged plants. Responses on the source of planting materials showed that 68.9% (n=193) used planting suckers from their own farms as opposed to 31.1% (n_{total}=87) of the farmers who received suckers from government projects, undefined neighborhood plantations, or research outlets.

More than 75% of the farmers grow non tissue culture cooking banana, whereas 24.3% grow tissue culture cooking banana, and other varieties. Notable among this category was the (0.4%) single farmer growing tissue culture dessert banana, and 17.9% (n=50) of the farmers in the region growing tissue culture cooking banana. This distribution is an epitome of non-adoption of the technology by smallholder farmers.

The yield factor variation

Smallholder farmers understand yield in an infrequent way of articulating units of measurement for the banana; the banana bunch, a unit of measurement clearly

Table 5. Response variables in the adoption of tissue culture banana technology.

Variable	Category	Frequency (n)	Percentage	Mean
Response variables				
Type of banana grown	Tissue culture banana	54	19.3	1.81±.395
	Non tissue culture banana	226	80.7	
Type of propagation materials	Plantlets	47	16.8	1.84±.374
	Conventional suckers	233	83.2	
% size of the field covered by TCB	1-25%	118	42.1	2.17±1.217
	26-50%	65	23.2	
	51-75%	28	10.0	
	75-100%	24.6	24.6	
Source of planting materials	Research outlet centers	15	5.4	2.86 ±.674
	Government projects	40	14.3	
	Farmers' own suckers	193	68.9	
	From neighborhoods	32	11.4	
Variety of the Banana grown	Tissue culture cooking banana	50	17.9	1.97±.735
	Non tissue culture cooking banana	212	75.7	
	Non Tissue culture Beer banana	15	5.4	
	Tissue culture Dessert banana	1	0.4	
	Non Tissue culture Dessert banana	2	0.7	

Source: Survey data 2017.

understood by the smallholder farmers but rather incoherent with the metric system in establishing the exact quantity of solid banana in possession. The total yield (in bunches) for cooking banana, brewing banana and dessert banana types was compared (Figure 1).

The yield for non-tissue culture cooking banana was higher for all responses. The mode for yield occurrence indicates lower numbers for the yields between zero and 500 bunches for estimated five consecutive production cycles, with the extraordinary farmers producing above 4,500 bunches for the five cropping cycles.

The production of dessert banana is much lower compared to the cooking type. Farmers produce about 3-5 bunches of dessert banana through the five production cycles as the lowest mode of occurrence. The highest single farmer recorded about 280 bunches of dessert banana over the five production cycles. Meanwhile, the production of beer banana in the region is not given much importance compared to cooking banana, although, beer banana production is much higher compared to dessert banana types. There are observable lower modes of occurrence at lower numbers of bunches produced for beer banana, with the highest single farmer producing about 470 bunches for the five consecutive production cycles.

A reasonably interesting input about the comparison of yield for banana types of the tissue culture origin and the non-tissue culture land race banana from the interviews and ratified by focused group discussions is that all key informants agree that tissue culture banana gives good yield because they are clean; free from pests and diseases. It was further revealed during the FDG 1 by the participant thus;

"It is not because the "Kawanda Bananas[1]" do not give a better yield, but because this better yield is short-lived. The tissue culture banana types hardly sustain productivity for five years. It is therefore, not necessary for [us] to venture into a project that would not last"

Other strong sentiments were expressed in terms of cost and taste preference by small holder farmers. Some of the sentiments were captured by the questionnaire and summarized under section 2.2.4.

[1] The name by which tissue culture bananas and other hybrid banana types are called by the small holder farmers.

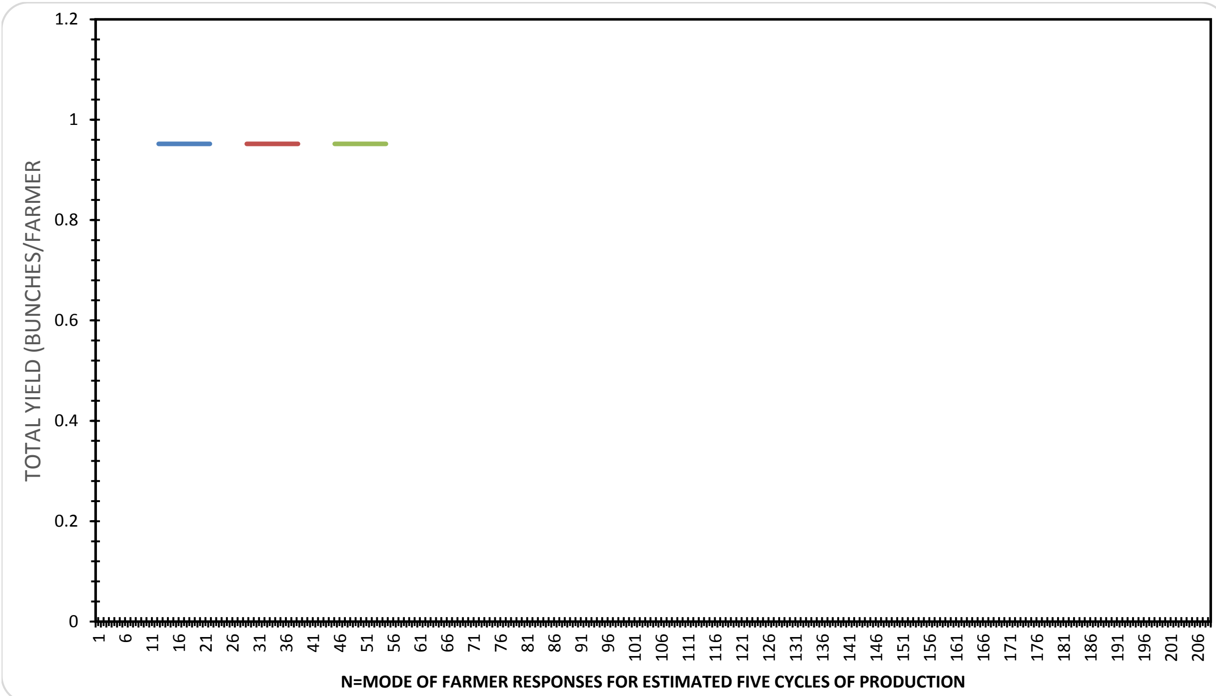

Figure 1. Yield factor estimations for the adoption of tissue culture banana.
Source: primary data.

Survey on market and preference factors

Market for the different types of banana grown in the region and the preference for consumption of the banana products were interrogated in the field (Table 6).

91.2% of the responses indicated that non-tissue culture cooking banana types (59.1% [n=167]) and non-tissue culture dessert banana types [32.1% (n=90)] have high market demand with attractive prices. However, in terms of preference for consumption, it was shown that 81.4% (n=228) of the population prefer to consume non tissue culture cooking banana type. Responses on market demand and consumption preferences for all tissue culture banana types were less than 13% for all the types combined together. For the peculiar submission on preferences during FDG 2 in Ibanda district, a female participant expressed concern about the current generation bananas,

"I sell bananas in my stall. Usually, the 'Kawanda bananas' are given a higher price, because they appear big in size, and have a smooth skin. Our local bananas are small and often times spotted; but in a single day, I receive more clients demanding for local types than the Kawanda types except in cases where these bananas are purchased for parties, then we benefit from their high prices"

This qualitative submission brings out the background meaning embedded in the preferences and cost attached to the types of banana. It further gives a clue on the identification and differentiation of tissue culture and non-tissue culture banana types.

Regression analyses

A linear model was used to estimate the probability of a positive influence of explanatory factors towards the adoption of tissue culture banana technology by smallholder farmers. Marginal effects computed for the socio -economic factors and their influence on tissue culture banana technology adoption in this model measured the expected change in the probability of observing a positive influence on the tissue culture banana technology with respect to a change in the particular yield response variable. In terms of the overall percentage of predictions correctly classified, the model performed well for all PCA isolated explanatory and response variables, thus implying a good fit. "Tolerance" and "Variance Inflation Factor"(VIF) values for all the predictor variables ruled out multi-colinearity to a higher

Table 6. Market and Preference considerations in smallholder banana production.

Parameter	Value						
Banana type has a high market with attractive prices							
				Valid			
	1	2	3	4	5	6	Total
Frequency	6.0	167.0	8.0	8.0	1.0	90.0	280
Percent	2.1	59.6	2.9	2.9	0.4	32.1	100
Valid Percent	2.1	59.6	2.9	2.9	0.4	32.1	100
Cumulative Percent	2.1	61.8	64.6	67.5	67.9	100.0	
Banana type is most preferred for consumption							
Frequency	13	228	1	2	34	2	280
Percent	4.6	81.4	0.4	0.7	12.1	0.7	100
Valid percent	4.6	81.4	0.4	0.7	12.1	0.7	100
Cumulative percent	4.6	86.1	86.4	87.1	99.3	100	

1= Tissue culture cooking banana; 2= Non tissue culture cooking banana; 3= Tissue culture brewing banana;, 4= Non tissue culture brewing banana; 5= Tissue culture dessert banana; 6= Non tissue culture dessert banana.
Source, survey data 2017.

estimation. The tolerance value indicates the fraction of variance in the predictor that cannot be accounted for by the other predictors. Tolerance values obtained for this study (Table 7a, b, c) explained variances that were large enough (all above 60%) to rule out predictors that were redundant (small values ≤ 10%). The most independent predictor at 97.7% level of tolerance was costs of production involved in the production of tissue culture banana. Labor for the value chain independently predicted 97.5%, while land tenure systems variance prediction could be tolerated at 89.7%. Age of the farmers could be tolerated as an independent predictor of yield at 77.2%. Household management independently predicted yield by 71.3% level of tolerance. Farmers' source of income and gender of the farmers showed the least levels of tolerance at 69.2 and 66.9%, respectively. All predictor variables indicated variance inflation factor values ≥1and ≤ 10, (Table 7a, b, c), thus the variables did not merit further interrogation and exploration. Gender, household management, labor sources for banana production value chain, land tenure systems, and costs involved in the production of banana were significant contributors to yield of cooking banana (P<0.05) (Table 7a).

Only age of the farmers significantly contributed to yield of beer banana (P=0.005) (Table 7b). Age of the farmers, household management and farmers source of income significantly contributed to yield of dessert banana (P<0.05) (Table 7c).

Source of the materials and management of the planting materials significantly determined the yield of the cooking banana type (P< 0.005). There is a very strong and significant relationship between source of the materials, and the type banana grown, variety of tissue culture banana and management of the sourced materials (P<0.05) (Table 8).

Whereas there is a significant interaction between individual factors that act together to determine the yield of beer banana, the overall factors' interaction shows no effect on the yield of beer banana. Each of the factors significantly interact with at least one factor to determine the yield dynamics of the beer banana (Table 9).

There is a significant relationship when two individual factors interact in causing an effect on the yield of dessert banana. However, when all factors are combined together, their overall effect on the yield of dessert banana is insignificant. Each of the factors significantly interacts with at least one factor to determine the yield dynamics of the dessert banana (Table 10).

DISCUSSION

The empirical results estimating the influence of socio-economic factors on tissue culture banana technology adoption at smallholder farmer level are discussed in this section. The study hypothesized that socioeconomic factors influencing the tissue culture banana technology uptake are not farmer -based, and so are beyond the smallholder farmer. For small holder farmers to accept tissue culture banana technologies, the foremost consideration is the yield benefit accruing from the

Table 7a. Regressed predictor factors for yield approximate for cooking banana (bunches/farmer)
Source; survey data 2017

Model		Coefficients											
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	7.685E2	2.888E2		2.661E0	0.008	1.999E2	1.337E3					
	Gender	-2.571E2	9.133E1	-0.199	-2.815E0	0.005	-4.369E2	-7.733E1	0-.142	-.168	-.163	.669	1.495E0
	Age of the farmer	-5.855E1	5.251E1	-0.073	-1.115E0	0.266	-1.619E2	4.482E1	-0.169	-0.067	-0.064	0.772	1.296E0
	Level of education	3.534E1	4.578E1	00.052	.772	0.441	-5.479E1	1.255E2	0.046	0.047	0.045	0.736	1.358E0
	House hold management	1.190E2	4.591E1	00.178	2.593E0	0.010	2.866E1	2.094E2	0.130	0.155	0.150	0.713	1.402E0
	Labor for the value chain	-1.526E2	7.176E1	-00.125	-2.126E0	0.034	-2.938E2	-1.128E1	-0.152	-0.128	-0.123	0.963	1.038E0
	Land tenure	240.498	48.700	00.286	4.938	0.000	144.621	336.375	0.250	0.287	0.271	0.897	1.115E0
	Cost of production	63.469	22.374	00.158	2.837	0.005	19.420	107.518	0.134	0.170	0.156	0.975	1.025E0
	Farmers' source of income	4.989E1	4.930E1	00.070	1.012E0	0.312	-4.717E1	1.470E2	0.031	0.061	0.059	0.692	1.445E0

Dependent Variable: Total Yield approximate of Cooking banana Source: Survey data 2017.

Table 7b. Regressed predictor factors for yield approximate for beer banana (bunches/farmer).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	17.602	16.833		1.046	0.297	-15.537	50.741					
	Gender of the	-4.570	5.323	-0.062	-0.859	0.391	-15.049	5.909	0.047	-0.052	-0.051	0.669	1.495
	Age of the farmer	8.633	3.060	0.190	2.821	0.005	2.609	14.658	0.161	0.168	0.167	0.772	1.296
	Level of education	-2.485	2.668	-0.064	-.931	0.352	-7.738	2.768	-00.099	-00.056	-00.055	00.736	1.358
	House hold management	2.545	2.676	0.067	.951	0.342	-2.723	7.813	0.035	0.057	0.056	0.713	1.402
	Labor for the value chain	-6.846	4.182	-0.099	-1.637	0.103	-15.081	1.388	-0.088	-0.099	-0.097	0.963	1.038
	Farmers' source of income	0.816	2.874	0.020	0.284	0.777	-4.842	6.473	0.100	0.017	0.017	0.692	1.445
	Land tenure	3.222	2.996	0.067	10.075	0.283	-2.676	9.120	0.063	0.065	0.064	0.897	1.115
	Cost of production	-0.669	1.376	-0.029	-0.486	0.627	-3.378	2.041	-0.030	-0.029	-0.029	0.975	1.025

Dependent Variable: Total yield approximate of Beer Banana.
Source: Survey data 2017.

Table 7c. Regressed predictor factors for yield approximate for dessert banana (bunches/farmer).

Model		Coefficients											
		Unstandardized coef.		Standardized coef.	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	26.054	16.496		1.579	0.115	-6.423	58.530					
	Gender of the	-5.943	6.263	-0.065	-0.949	0.344	-18.272	6.387	-0.107	-0.057	-0.053	0.672	1.489
	Age of the farmer	8.793	3.615	0.156	2.432	0.016	1.675	15.910	0.136	0.146	0.137	0.769	1.301
	House hold management	-6.578	3.204	-0.139	-2.053	0.041	-12.886	-0.270	-0.224	-0.124	-0.116	0.691	1.446
	Land tenure	6.536	3.528	0.110	1.852	0.065	-0.411	13.482	0.088	0.112	0.104	0.897	1.115
	Labor for the value chain	7.547	4.933	0.088	1.530	0.127	-2.166	17.259	0.139	0.092	0.086	0.962	1.040
	Farmers' source of income	-9.468	3.165	-0.189	-2.992	0.003	-15.699	-3.237	-0.243	-0.178	-0.169	0.793	1.261
	Cost of production	2.185	1.621	0.077	1.348	0.179	-1.006	5.377	0.109	0.081	0.076	0.975	1.025

Dependent Variable: Total yield approximate of Dessert Banana. Source: Survey data 2017.

Table 8. The relationship between response factors and yield of cooking banana.

Parameter		A	B	C	D	E	F
Sig. (1-tailed)	Yield of Cooking banana (A)	-	0.296	0.093	0.253	0.000	0.000
	Type of banana grown (B)	0.296	-	0.000	0.000	0.000	0.133
	Variety of TCB grown (C)	0.093	0.000	-	0.000	0.000	0.360
	Type of propagation materials(D)	0.253	0.000	0.000	-	0.000	0.025
	Source of the materials (E)	0.000	0.000	0.000	0.000	-	0.000
	Management of the materials (F)	0.000	0.133	0.360	0.025	0.000	.
	N	280	280	280	280	280	280

Source: Survey data 2017.

technology. The yield benefits are related to the inputs such as land, labor and other accessory costs involved in the production of the technology. Besides yield, smallholder farmers are cognizant of the fact that their social values as largely shaped by the culture are preserved. Therefore, a high yielding technology, which corroborates the socio-economic orientations of the farmers is easily accepted. Actually Smith (2007) earlier

Table 9. The relationship between response factors and yield of beer banana.

Parameter		A	B	C	D	E	F
Sig. (1-tailed)	Yield of Beer banana (A)	-	0.233	0.101	0.143	0.221	0.213
	Type of banana grown (B)	0.233	-	0.000	0.000	0.000	0.133
	Variety of TCB grown (C)	0.101	0.000	0.	0.000	0.000	0.360
	Type of propagation materials(D)	0.143	0.000	0.000	-	0.000	0.025
	Source of the materials (E)	0.221	0.000	0.000	0.000	-	0.000
	Management of the materials (F)	0.213	0.133	0.360	0.025	0.000	-
	N	280	280	280	280	280	280

Table 10. The relationship between response factors and yield of dessert banana.

Parameter		A	B	C	D	E	F
Sig. (1-tailed)	Yield of Dessert banana (A)	0.	0.217	0.362	0.172	0.276	0.241
	Type of banana grown (B)	0.217	0.	0.000	0.000	0.000	0.133
	Variety of TCB grown (C)	0.362	0.000	0.	0.000	0.000	0.360
	Type of propagation materials(D)	0.172	0.000	0.000	0.	0.000	0.025
	Source of the materials (E)	0.276	0.000	0.000	0.000	0.	0.000
	Management of the materials (F)	0.241	0.133	0.360	0.025	0.000	0.
	N	280	280	280	280	280	280

Source: Survey data 2017.

argued that that a technology is often valued according to whom it is associated, with, rather than by its utility. Even with a clear comprehension of the "yield decline" narratives in banana production, threats to the economy, livelihoods and food security, a desirable internal momentum within the smallholder farmers has not been created to adopt tissue culture banana technology to solve the threats. Small scale farmers still associate the technology to scientists and policymakers. To these farmers, the technology in reality is more of a burden than a necessity.

Levels of tissue culture adoption in Uganda

The level of adoption for tissue culture banana technology was found to be very low on all traits ranging from acceptance of plantlets, marketing and finally to consumption. Farmers rejected the tissue culture banana products including the plantlets and the harvested products. Fall back for those who had accepted the technology remains eminent. Indicators for non-adoption were evident in the allocation of available resources to the accepted technology. Allocation of land resources to tissue culture banana production was diminutive. Research centers and other government projects lack capacity/ability to shoulder the socio -economic demands that would support the acceptance of tissue culture banana technologies.

The farmers argument that tissue culture banana gives good yield and the reason advanced in their arguments that the planting materials are clean, and free from pests and diseases holds truth and corroborates with Singh et al. (2011), who, in giving deeper meaning to development of tissue culture technology as a foundation of high quality, fronted the fact that planting materials are disease free. An outstanding reason established by this study as to why smallholder farmers hesitate to adopt the technology is mainly the sustainability of the technology. Customarily, banana is grown as a perennial crop where the plant marts produce continuous shoots from a subterranean corm, and depending on the level of management yield may start to decline after ten to fifteen years. In tissue culture banana technologies, the yields fall rapidly after three to five years, thus creating need to shift to cyclic replacement with a new plantation. This practice is expensive and incomprehensible to the smallholder farmers.

Smallholder farmers use suckers from their own orchards. Where the planting suckers are not sufficient, corms of recently harvested banana are used as planting materials. These corms regenerate into suckers that eventually grow into strong plants. This orientation of planting suckers and corms suggests a direction of thought that diverges from, Tushemereirwe et al. (2003), who assert that use of suckers and corms in banana production perpetuates banana weevil and diseases.. The suckers obtained from farmers' own gardens and from the neighborhoods continue to take precedence. This is due to low cost and availability when compared to plantlets developed by tissue culture processes. The tissue culture banana plantlets are limited to the "resource endowed" farmers. The resource -endowed farmers have the ability to foot the high costs involved in buying, transporting and maintaining the tissue culture banana plants into the fields. It therefore follows that small-scale farmers who are largely not resource bequest will keep within the confines of cheap source of planting materials. Farmers using their farm-derived materials for planting accord them the satisfaction that curtails the need to use cleaned suckers from other sources, thus, propagation of the same surpasses the acceptance and propagation of tissue culture banana.

There is a very strong attachment to production of cooking banana for both social and economic reasons. Actually, smallholder farmers insist on having good and well tendered orchards which raise the social status of the farmers, improve on the social capital, and most importantly, guarantee the food security of the farmer. Smallholder farmers who make substantial food contributions to the communities' social functions are often more respected than those who do not. There is however, a moderate improvement in the production of beer banana types regardless of whether they are tissue culture or non-tissue culture banana. The explanations are vested in the versatility of the products and bi-products, most of which have socio economic orientations. For instance, drawing from the farmer focused discussions; the banana brewing produces *Waragi*[2] that significantly contributes to the income base of the households and the social status of the farmers. Residues from the brewing process are ploughed back into the soil for the production of other banana types. The residues are also important sources of mulch, and feed for animals. Meanwhile, the dessert and cooking banana types are used by some farmers to produce juices that are fermented into alcohol and subsequent production of other residues for use in banana crop production. Thus, the type of banana contributes to the social capital dynamics.

An understanding of the responses in this study is drawn from the fact that the largest number of the participants was males. A review by Mwangi and Kariuki (2015) indicates that gender issues in agricultural technology adoption have been explored for a long time, although, the studies have not been explicit regarding the different roles men and women play in technology adoption (Mignouna et al., 2011; Obisesan 2014; Mwangi and Kariuki 2015). Social systems appear to assign the male gender those practices that are more economically superior. The participation of the male gender is an indicator of the profitability of the banana growing project even at small -holder farmer level. Whereas the females' practices and involvement in banana production projects may greatly be driven by food security orientation (Husen et al., 2017), the men's impetus is in most cases financial (Alinovi et al., 2010). This understanding contravenes earlier arguments that the association between gender and the probability of adoption of agricultural technology is rather not s ignificant. This could be true for other crops such as maize, but untrue in the case of tissue culture banana adoption. Majorly, men are the bread earners in the local family settings and therefore, quickly adopt a practice that supports the economic status of the families. If in this context males have an obligation to provide for the family, and land races provide a greater solution to this duty, then the tissue culture banana technologies cannot benefit either gender in the same way. Therefore, male farmers are more likely to fall back to tissue culture banana production if it enhances the role of the head of the family.

The study established that age has a stake in adoption of new agricultural technology, but does not stand alone in decision making whether to adopt or reject tissue culture banana technology. Mature and experienced farmers have a long term understanding and experience, hence are better placed to evaluate new technology practices and demands than younger farmers. Whereas there is increased risk aversion and decreased interest in long-term investment as the farmers grow old (Obisesan 2014), it would be argued that younger farmers are less risk-averse and therefore would be more willing to take up tissue culture banana production as a new technology. On the contrary, the products from tissue culture process are stagnated even with increased number of younger farmers (20.4%) venturing into banana farming. Dynamics in banana production are largely influenced by 40% of the farmers in the middle age category (30-49 years). This age bracket is indeed a working group and most often result- oriented. The high number of young people engaging in smallholder banana farming is not due to passion as such, but rather an alternative occupation due to limited opportunities for formal employment.

Supporting structures in the banana production

[2]The local name of the spirit distilled from fermented banana juice and yeast. It is used at social functions and for commercial processing of other spirits.

practices are enhanced by land tenure systems. Most of the operational land is inherited from the fore-parents. The study further established that over 80% of the banana plantations are traditional; implying that they have been perpetuated from generation to generation. The social systems usually dictate the conditions for use of such inherited land systems. It can be concluded that tissue culture banana technologies in Uganda are nascent and probably has not caused a strong impact that can be inherited, defended, and sustained by smallholder farmers. Inherited social systems in banana production stretch to the use of labor in banana production (Komarek et al., 2013). Time and time again, smallholder farmers rely frequently on family labor. Family labor benefits from the household size, an indicator of the extent of labor availability in smallholder production systems. It determines adoption process in tissue culture banana production in that, larger households have the capability to subdue the labor limitations vital for tissue culture banana introduction. Other forms of labor, including professional labor are left to the resource endowed and extraordinary farmers. The low adoption rates t reflects a nature of the households such that households cannot raise sufficient labor to offset tissue culture banana production demands.

Over 55% of the households are male headed. Social and economic decisions to accept or reject tissue culture banana production are vested in the household head. Even though much of conservative research accepts that the 'head' of the household is male, farmers' experiences in Uganda currently challenge this orientation. What is conventional in this study is that both male headed and female headed households make decisions that do not support the production of tissue culture banana technology products. Otherwise, the 31% of the households headed by females would make a significant contribution to the acceptance of tissue culture banana products. It is argued in this study that introducing tissue culture banana products to a predominantly subsistence banana biased production systems creates a need for socio economic change first. However, earlier Etwire et al. (2013), Geoffrey (2016) and Bandewar et al. (2017a) observed that socio -economic changes are difficult to achieve in the process of introducing new farming techniques. As long as the smallholder farmer tenaciously holds to landrace banana production as a practice that is socio-economically gratifying, acceptance of the tissue culture banana is not a priority for them.

Yield factor variations and influence for adoption

The premise of the study in this area was that yield is a pertinent factor in the adoption of tissue culture banana technology. This premise is backed by Chitamba et al. (2016), that a technology that brings forth a sustainable yield is definitely accepted by smallholder farmers. An honest; though misleading understanding by the smallholder farmers was that the ability of the banana plants to produce a sustainable amount of bunches to meet family survival needs depends on the total number of suckers a local banana mart holds. The number of suckers produced would be the number of bunches at harvest period. However, yield performance of the banana plant depends on the management by the farmers amidst a host of other biophysical interactions (Wairegi and Asten 2010; Nyombi, 2013; Nakato et al., 2017; Bandewar et al., 2017b). The management practices are constrained by land tenure systems, labor dynamics, as well as level of income and the income sources.

The yield for non-tissue culture cooking banana was higher, with farmers extraordinarily producing about 4500 bunches through the five cropping cycles, while production of beer banana is slightly higher compared to dessert banana types, with extraordinary farmers producing about 300 and 280 bunches respectively. Discussions with the farmers showed that the current changes in social systems promote the use of the different types of bananas variedly. The variations are attributed to the societal dynamics that spill over to the production systems of the banana and the traditional beer parties have since reduced. For instance, cooking banana is an item that forms part of the valued gifts during spiritual and social household gatherings. On the other hand, processing of *Tonto* into a spirit that attracts slightly high prices is slowly attracting the households into the production of beer banana.

Market and consumer preferences

Non-tissue culture bananas attract good prices on the market, and in terms of preference for consumption, the populace prefers non- tissue culture cooking banana type. This result generally agrees with FAO (2014) and UNCTAD (2016), that assert that inclination for traditional banana can incline the preference factors towards the market potential of this banana. The dissenting assertiveness towards tissue culture banana is a result of market considerations for the different types of banana grown in the region. The attitude towards tissue culture banana products is wanting even when there are free channels for the farmers to receive plantlets.

The idea as to whether consumers and sellers can tell the difference on site between tissue culture banana and the land races is inconsistent although several discussions point to a near judgment. It is observed that, the cost of banana vaguely shows which type it is. It was shown that higher prices are attached to tissue culture bananas but their actual consumption is limited to big social functions. The second aspect is the size, where the bigger the size of the banana, the higher the likelihood of that banana being a 'Kawanda Banana'. The third aspect is the texture. Whereas the landraces are rough and spotted, the bananas of the tissue culture origin are herein described as smooth skin bananas.

Demographic features and their influence of adoption

The study established that gender, household management, labor sources for banana production value chain, land tenure systems, and costs involved in the production of banana were significant contributors to yield of cooking banana. Marginal effects figured out for the socio- economic factors and their influence on tissue culture banana technology adoption in the linear model, measured the expected change in the probability of observing a positive influence on the tissue culture banana technology with respect to a change in the particular yield related to a response variable. Social demographics contribute positively to the decision to adopt a particular banana type and its related technology. In the study, males formed the largest response rate and following studies by Dube (2017) the male gender social constructs role directly links to products that attract high prices. It can then be argued that, the economic returns of the non-tissue culture banana technology are sufficient enough to attract males more than any other gender. This study established that, non-tissue culture banana products attract higher prices on the market compared to any other banana type. The decision to accept, support and finance the new tissue culture banana technology is greatly attached to the male-gender social construct. Males dominate household leadership, thus, have control over labor, land and are entitled to inheritance of other livelihood enhancing resources. Can the same be said for women? Certainly not! What is certain and conventional is that, regardless of age, this gendered 'order' places the women in the responsibility of much of the day-to-day household, family, and on-farm labor activities (Rosemarie, 2010). A popular understanding of a "good wife" varied from district to district. However, the common understanding was that a good wife relates to a measure of how she positively realizes her multiple responsibilities to the household, especially through her prominent role as a farmer contributing to sufficient production of landrace banana.

Households rely mainly on family labor. In most cases family labor is too rudimentary to match the labor demands for tissue culture banana production. Besides, labor is allocated to the banana type that is marketable and consumable by the smallholder farmers. Therefore, the available force is maximized for the production of non-tissue culture banana due to high market and preference requirements. It can further be argued that the labor requirements for production of non-tissue culture banana are lower within the management by the small holder farmers. Other forms of labor are rather expensive to be managed by the smallholder farmers. Besides, particular farmers in the region are worried that if they employed professional labor, it would result in the introduction of the "*Kawanda Bananas*[3]". Professional labor force is visibly insufficient to explain to farmers some of these concepts. As matter of fact, the smallholder farmers blend their understanding of tissue culture bananas, improved or hybrid, bananas and the genetically modified bananas. To farmers, all the three types are the same, and are from the same source, meant to dilute their local land race types.

The results of the study clearly showed that land owned by the smallholder farmers is inherited from the previous owners. The significance of land tenure in influencing the yield and acceptance of non-tissue culture banana production draws from the fact that, land on which production is made is inherited from the fore owners, whose interests and social dictates are usually followed. The source from which land is acquired usually dictates the continuity of the land use and type of production carried out on the same land. Therefore, the inherited and long lasting non-tissue culture traditional banana orchards provide socio-economic benefits that cannot be surpassed by the new technology. Otherwise, the latter would lead to the destruction of the old plantations for re-establishment of tissue culture banana types. This understanding is backed up by yet another finding of the study that the costs involved in tissue culture production value chain in terms of plantlets' development; purchasing, transportation and management in the field are a burden to the small- holder farmers. The alternative plan for the smallholder farmers is to use the farmers' own suckers, and those obtained from the neighborhood. This edges out the production of tissue culture banana products in preference to the conventional less expensive banana type.

Components within the demographic characteristics are significant factors in shaping decisions regarding the uptake of tissue culture banana technology. The attributes attached to the social factors lead to significant yield levels ($P \leq 0.05$), for at least one type of banana

[3] The name by which smallholder farmers know the banana products from the National Research Organization, located at Kawanda.

produced by small- holder farmers (Table 7a, b, c) Interests for adoption vary with age and gender. Age and gender are associated with a short time preference for the types of banana. Hence, they determine the decision to sustain the adoption or fall back to rejection. Other than age, the other demographic variables progressively become negatively associated with the probability of adoption and production of beer banana as the productivity proceeds from cycle to cycle. Although Husen et al. (2017) indicate a negative relationship between age and the adoption of some agricultural technologies in Ethiopia, and Ssentamu et al. (2012) and Rosemarie (2010) disassociated gender issues as a factor in new technology acceptance in Kenya and Philippines respectively, and these are contrary to the findings of this study for Uganda as far as tissue culture banana technology is concerned.

The contributing effect of farm characteristics

Yield remains a precursor to adoption of tissue culture banana technology. The enablers for this yield as predicted by the total number of bunches estimated for five production cycles are source of the materials for planting and the management approaches of the planting materials. They extend to the type of banana grown, method of propagation and the variety of banana grown. These significantly determine the yield of the different banana types ($P< 0.005$). The inter-factor interactions were very strong and significant ($P<0.05$), in determining the yield of the cooking banana. The overall factors' interaction shows no effect on the yield of beer banana ($P>0.05$), but the inter-factor relations in beer banana production are significant, with at least one factor interacting to determine the yield dynamics of the beer banana. Hence, non-adoption of tissue culture banana technologies cannot be blamed on the social and economic factors alone. There are other interacting factors in the process.

CONCLUSIONS AND POLICY DIRECTIONS

This study assessed the dynamics associated with adoption of tissue culture banana technology in Uganda, and established that the levels of adoption of this technology are still low. Above 75% of the farmers grow land race non tissue culture banana. Whereas the percentage of adoption rates for tissue culture banana is generally low for farmers in Uganda; the conclusion may not be generalized for the rest of the banana growing countries of the world, except those that present similar socio economic dynamics under which this study was conducted.

The yield of land race non tissue culture banana type is high due to increased number of farmers and increased acreage under production rather than the adoption of the technology. This orientation is not sustainable because smallholder farmers can have a paradigm shift along the production process. Additionally, land is a fixed asset that may not sustain increased production as a result of increase in acreage under production. Therefore, adoption of the technology would present a better choice for the small holder farmers. However, this would only occur if the technology is convincing enough to overcome the socio economic mindset of the smallholder farmers.

Market and taste preferences favor the non-tissue culture banana types. The farmers are solely responsible for the decision to adopt or reject tissue culture banana technology. This decision is enhanced by age, household leadership, land tenure systems, gender and sources of labor. Sustainability of the yield supports the decision for the smallholder farmers to adopt and sustain the technology, fall back to the former technology, and/or reject and sustain the rejection of the technology.

The indicators for adoption and or rejection become reflected in the size of the land allocated to the technology, choice of the propagation materials, source of the materials for propagation, and types of banana grown. The limitation behind such indicators is the subjectivity and/or objectivity of the farmers. Farmers who may have subjective impressions about the tissue culture banana technology will limit resource allocation to the technology, than the farmers who are objective about the same technology.

Economically poor farmers are labor constrained to sustain tissue culture banana technology demands. Socio- economically unstable smallholder farmers especially of the female gender are in the most precarious situations of all, ready to forego the adoption of tissue culture banana technologies as result of pressure from their social ancestry constitutions.

A systems wide approach is recommended to develop mechanisms that would improve the adoption of the technology in order to tap into its unknown immense advantages. There is a need to understand the smallholder farmers' perceptions of use attributes and the performance of tissue culture banana technologies as compared to the traditional/landrace banana production technologies to give farmers options by context. Finally, there should be a deliberate effort to respond to tissue culture banana adoption problems through processes that would establish a self-sustaining system of production, distribution and utilization of farmer-preferred varieties of tissue culture banana in Uganda. For instance, tissue culture banana processes, and hardening orchards should be exposed to the farmers not only to reorient the farmers' negative perceptions of the technology, but also to enable farmers' access to banana planting materials.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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