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Adoption Patterns and Intensity for Multiple BananaTechnologies in Uganda

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Abstract: The adoption of improved technologies is widely recognized as key to improving agricultural productivity in Sub-Saharan Africa. This study analyzes adoption patterns and intensity of multiple banana technologies in Uganda which have been promoted over time. We used primary data collected from 383 banana farmers sampled using a multi-stage sampling procedure. Multivariate probit (MVP) and ordered probit analyses were applied to establish the adoption patterns and adoption intensity, respectively, and any factors affecting them. The findings highlight that 15 pairwise correlation coefficients among banana technologies were statistically significant implying that banana farmers adopt technologies simultaneously. The household size, total banana area, ecological location, membership to farmer groups, access to formal credit sources, and the type of market accessed had significant effects on household adoption patterns and intensity. Thus, it is recommended that such factors should be seriously considered in addition to technology characteristics when planning promotion programs. Simultaneous adoption implies that each of the technologies should be considered as a package which contributes to the increased farmer options and maximum synergistic effects among them. This study contributes to the existing literature by highlighting the key variables which affect the pattern and intensity of adopting technological packages involving both input intensification and low-external-input technologies in Uganda.

Keywords: input intensification; low external inputs; multivariate probit; ordered probit; technology package

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1. Introduction

The world's population is projected to reach 9.15 billion people by 2050 [1] with the largest percentage increase expected in Sub-Saharan Africa (SSA). The rising population is associated with the increase in food demand; yet, the land resource for food production remains constant. Thus, unless there is extensive adoption of farming technologies to increase agricultural productivity on limited land, there will be a future threat to food security [2–5]. This is more likely to be experienced in SSA compared to other parts of the world because of the persistent low agricultural productivity in the region [6].

In Uganda for example, the agricultural sector continues to register a very slow growth rate of 3.4% (Uganda Bureau of Statistics) which increases the risks of poverty and food insecurity among 64.3% of the country's population who entirely depend on agriculture for food and income [7]. Uganda's agricultural sector is affected by pests and diseases, poor farming methods leading to land degradation, threats of climate change, lack of access to markets, and low adoption of improved technologies and practices [8]. To a large extent, these challenges are the root causes of low agricultural productivity across most of the SSA countries such as Uganda [1]. In order to overcome the challenges and improve productivity, it has been recommended to use input intensification packages such as inorganic fertilizers, pesticides, herbicides, hybrid varieties, and irrigation as a way of customizing green revolution experiences in SSA [2]. Other studies suggest the use of low-external-input technologies which involve the implementation of various agronomic practices such as the use of organic manure, mulching, cover crops, intercrops, and rotations to boost productivity [9,10], while others suggest a combination of input intensification and low external technologies in order to create synergistic productivity effects [11,12]. Investment in such technologies contributes to the increased productivity of key crops for food and income security such as bananas in Uganda [13,14].

Banana is a perennial crop grown by the majority of farmers and occupies 38% of the cultivable 1.4 million hectares of land. [15]. The most common varieties grown are the cooking types (AAA-EA) which have been grown in Uganda for over 150 years [16,17]. Banana plantations are regarded as household assets which are passed on from one generation to another [18,19]. However, the productivity of bananas in Uganda has been gradually declining countrywide; for instance, close to a 45% yield decline was reported across production regions since 2007 [18]. The declining trends could be attributed to a number of constraints including pests and diseases; lack of information on good management practices; lack of input and output markets; and soil degradation among others [20,21].

To reverse the declining trends, the National Banana Research Program (NBRP) was created in 1989 under the National Agricultural Research Organization (NARO) to specifically focus on research into how banana productivity can be improved and sustained countrywide [22]. The program has generated and implemented several initiatives towards improving productivity; among others, the initiatives include: the introduction of exotic FHIA varieties; the multiplication and promotion of *Matooke* hybrids [22,23]; the promotion of clean seed technology; the integration of livestock into banana-based farming systems and the modification of traditional banana management practices; the control of *Banana Xanthomonas Wilt* [24]; and the recent implementation of the banana agronomy project (2017–2020) that targeted bridging the on-farm banana productivity gap from 10 to 25 tons/hectare/year [19].

The banana agronomy project involved the promotion of a package of 14 banana technologies (Table 1) in order to simultaneously tackle the overlapping constraints to productivity in Uganda's banana sector. The nature of banana technologies can be described as input intensification technologies (inorganic fertilizers, herbicides, clean seed, and hybrid varieties) and low-external-input technologies, especially the modified traditional banana management practices [19]. Each of the banana practices has specific details of how it should be implemented. This reflects the complexity and the level of knowledge required in banana management. Consequently, it is more likely that farmers will choose to implement a combination of technologies in a step-wise manner depending on the convenience of using them, similar resource requirements, and complementarity in their use [25]. Thus, establishment of the combinations or patterns in which the households choose to implement the technologies and the number of technologies that can be implemented at a time provide insights into technological packaging to increase adoption. This is useful for guiding further scaling of banana technologies. Previous adoption studies with regard to bananas mainly covered the adoption of individual technologies [22,23], ignoring the fact that they can be adopted in combination as complementarities or substitutes [26–28]. The studies give recommendations for a single technology adoption; yet, banana production is faced with a myriad of challenges, whose solution requires the urgent implementation and adoption of various technologies. There is still a gap with regard to what influences the adoption of complete technology packages by banana farming households. This study fills the gap by providing answers to the following research questions: (a) In what patterns do banana households adopt multiple technologies? What influences the observed adoption patterns of multiple banana technologies among households? (b) What is the intensity (number of technologies) of adopting banana technologies? What influences the adoption intensity of multiple banana technologies?

Table 1. Household and farm characteristics.

Variable Description		Low Adopters (*n*= 33)		Mid Adopters (*n* = 208)		High Adopters (*n* = 92)		Expected Sign
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Socioeconomic characteristics								
Gender of household (hh) head	1 if female; 0 if male	0.15	-	0.11	-	0.08	-	+/−
Marital status of the hh head	1 if married; 0 otherwise	0.79	-	0.79	-	0.82	-	+/−
Household size	No. of people in household	6	2.90	6	2.60	7	3.30	+/−
Hh experience growing bananas	No. of years growing bananas	22.52	15.94	17.49	13.38	18.30	11.96	+/−
Hh income source	1 if farming; 0 otherwise	0.82	-	0.93	-	0.90	-	+
Why they grow bananas	1 if subsistence; 0 if commercial	0.64	-	0.56	-	0.51	-	+
Physical farm characteristics								
Total land accessed	Total land operated by the household (ha)	1.87	2.94	1.59	2.16	1.64	1.45	+
Total land under bananas	Total land where bananas are planted (ha)	0.43	0.37	0.65	0.59	0.70	0.57	+
Ecological location	1 dry corridor if Nakaseke and Birere and 0 if Rwimi	0.64	-	0.62	-	0.68	-	+
Physical location	1 if hilly and 0 if flat or valley	0.61	-	0.50	-	0.51	-	+
Soil fertility status 1	1 if high soil fertility and 0 if medium or low soil fertility	0.18	-	0.25	-	0.33	-	+/−
Soil fertility status 3	1 if medium and 0 if high or low	0.48	-	0.44	-	0.46	-	+/−
Access to Agricultural support services								
Access to formal credit sources	1 if formal (banks, SACCOs, and VISLAS) and 0 otherwise	0.30	-	0.56	-	0.67	-	+
Input/output market access	1 if major towns and 0 if farm gate/local markets	0.18	-	0.18	-	0.29	-	+
Distance to the market	Distance to the nearby market	4.16	4.14	5.88	5.20	5.05	4.71	-
Cost of transport to the market	Cost of transport to input/output markets	2364	2013	3204	2166	2842	1910	-
Contact with extension	1 if yes and 0 otherwise	0.88	-	0.96	-	0.97	-	+
Membership to a farmer group	1 if yes and 0 otherwise	0.09	-	0.37	-	0.50	-	+

The rest of the paper is organized as follows: Section 2 presents materials and methods in which the study area, sampling procedure, data collection, and estimation strategy are described. Results and discussions mainly focusing on the adoption patterns and intensity of multiple banana technologies are presented in Section 3. Last, concluding remarks, policy implications, and areas for further research based on key findings are highlighted in Section 4.

2. Materials and Methods

2.1. Study Area and Data Collection

This study was conducted in the central, midwestern and southwestern regions of Uganda, specifically in the Nakaseke, Bunyangabu and Isingiro districts, respectively. The regions represent lowland, highland and mid-highland agroecological zones in Uganda predominantly known for banana production [29]. Close to 64% of households in Nakaseke are engaged in banana growing, with an average plot size of 0.2 hectares [30]. Bunyangabu district has 83% of the population engaged in banana production with an average plot size of 0.2 hectares per household [31]. It is characterized by the mountainous high-fertility soils which support the growth of a wide range of crops. Isingiro district is characterized by steep hills and deep valleys while others are gentle slopes and low land areas. The district has a deep loamy well-drained soil type that supports banana production [32]. In this area, 70% of the population entirely depends on bananas as their sole economic activity on 0.4 hectares per household [33]. The characteristics of these districts in terms of their level of banana production informed the choice of selecting them as sites for this study.

Primary data were obtained using a semi-structured questionnaire from 383 sampled households. The instrument contained a mix of structured and open-ended questions. The tool used is presented in the Supplementary Material section. Only one adult was interviewed in each household to avoid pseudo replication. The data collected covered: (i) banana technologies implemented such as: de-trashing; male bud removal; use of organic manure; use of inorganic fertilizers; use of clean seed; digging of trenches and basins and desilting them; use of hybrid varieties; de-suckering; and corm removal; (ii) household socioeconomic status in terms of: gender of the household head; marital status; number of years in school; family size; major income source of the household; household banana growing experience and total land owned; (iii) access to support services in terms of: membership to farmer groups and household access and receipt of credit and contact with agricultural extension; (iv) the physical farm characteristics considered were farmer perception of farm soil fertility and physical location of the farm. Data collection was conducted from December 2019 to mid-March 2020. The instrument was first pretested to examine the appropriateness of the set questions and based on the result of the pretest, some questions were modified and others deleted before the actual data collection in the study area.

2.2. Sampling Procedure

A multi-stage sampling procedure was applied to select sample households. Stage one involved purposive selection of three different agroecological zones and respective districts where bananas are traditionally produced. Stage two involved purposive selection of one sub-county per district given that there have been deliberate efforts of the NBRP and partners to promote banana technologies in those sub-counties. The three sub-counties selected were Nakaseke, Rwimi and Birere, located in Nakaseke, Bunyangabu and Isingiro districts. The total number of banana farming households in each of the sub-counties was 2789, 3230 and 3132 for Nakaseke, Birere and Rwimi, respectively, which gave a total of 9151 [19]. This total makes the sampling frame. In the final stage, we applied a simple random sampling approach to select the households using the Yamane [34] sample size estimator as expressed in Equation (1).

$$n = \frac{N}{(1 + N(e)^2)} \tag{1}$$

where n = sample size.
N = Total number of banana households in the three sub-counties, i.e., 3132 + 3230 + 2789 = 9151.
e = Margin of error (5%).

Therefore, the sample size,

$$n = \frac{9151}{9151(1+9151(0.005^2))} = 383 \text{ households}$$

The number of respondents from each sub-county to make a total of 383 depended on the probability proportional to the number of banana farming households in each. A list of banana farmers per sub-county was obtained from the inventory of banana farmers provided by the NBRP. The actual respondent households were selected using skip counting until the intended total number was attained.

2.3. Data Analysis

Data were entered and cleaned for statistical analysis using Microsoft Excel. It involved checking for completeness and outlier responses which resulted in the elimination of data from 50 households out of 383 initially considered. Thus, the analysis for this study was based on reliable and complete data from 333 households. The clean data were then imported into Stata 14 and analysis was conducted to produce descriptive and econometric results in response to the research questions.

2.3.1. The Multivariate Probit (MVP) Model

The multivariate probit (MVP) model was used to analyze patterns and the drivers of adopting banana technologies. The MVP model is appropriate for estimating multiple adoption decisions in the presence of adoption interdependence [11]. It recognizes the correlation in the error terms of the adoption equations [35]. Given that banana technologies are not mutually exclusive, the decision to adopt one of the technologies may influence the decision to adopt other technologies. The application of MVP to analyze the adoption patterns and drivers of multiple interrelated technologies was more appropriate compared to the estimation of univariate logit, probit and multinomial regressions. Such models assume the independence of error terms, thus excluding relevant information on interdependent and simultaneous adoption patterns [11,12,36]. Estimations without considering the synergies (complementarities) and trade-offs (substitutability) of banana technology adoption would produce inefficient and biased estimates of the determinants of adoption patterns.

The variables used in the analysis were selected based on the past empirical adoption literature [3,22,23,37–40]. A set of nine technologies, namely, mulching, use of herbicides, organic manuring, use of clean seed, use of trenches, basins and desilting them, use of sterilized tools, weevil trapping, and use of hybrid banana varieties, were chosen as a dependent variable for MVP estimation in this study. The other technologies such as de-trashing, corm removal, de-suckering and male bud removal are regarded as basic technologies because they were implemented by almost all banana farming households, and those implemented by very few farmers such as the application of inorganic fertilizers [19] were excluded from the MVP model. The exclusion was because this extreme number of households, once included in the model, would produce biased results [41]. Details of the variables used are presented in Table 1. To fulfil the assumption of normality, the total land accessed and total area under bananas and the cost of transport to the input and output markets in major towns were transformed before using them in model estimation [35].

It is hypothesized that a farming household is more likely to adopt a particular banana technology if the benefits of its adoption are higher than those obtained without adoption [42]. Consider the *i*th farming household ($I = 1, 2, \ldots .. N$) that faces the decision on whether to adopt an *i*th banana technology on its farm. Let U_0 and U_j represent the benefits to a farmer without and with the adoption of a particular banana technology. A household will adopt the *i*th banana technology if the net benefits (B^*_{ij}) with its adoption are higher than without its adoption, i.e., $B^*_{ij} = U_j - U_0 > 0$. In this case, the net benefits of adopting banana technologies are taken as a latent variable, which is determined by the observed household socioeconomic status, access to support services and physical farm characteristics (X_i) and the error term or unobserved characteristics ε_i as presented in (2) below:

$$B^*_{ij} = X'_i\beta_j + \varepsilon_i \qquad (\text{j} = \text{banana technology}) \tag{2}$$

Equation (2) can be presented in terms of an indicator equation where the unobserved preferences in Equation (2) translate into the observed binary outcome equation for each banana technology as follows:

$$B_{ij} = \begin{cases} 1\ if B^*_{ij} > 0 \\ 0\ otherwise \end{cases} \qquad (\text{j} = \text{banana technologies}) \tag{3}$$

In the MVP model, the error terms jointly follow a multivariate normal distribution with zero means and variance normalized to unity (0, Ω). Thus, the covariance matrix (Ω) is given by:

$$\Omega = \begin{bmatrix} 1 & \varepsilon_{12} & \varepsilon_{1j} \\ \varepsilon_{21} & 1 & \varepsilon_{2j} \\ \ldots & \ldots & \ldots \\ \varepsilon_{1j} & \varepsilon_{2j} & 1 \end{bmatrix} \tag{4}$$

2.3.2. The Ordered Probit Model

Following Greene [42], we further measured the intensity of adoption by taking the number of technologies adopted by the households as the dependent variable. The study assumed that: (i) provided a household derives greater utility from the last adopted technology, there is no limit to the number of technologies adopted; (ii) the adoption decision of the farming household for any one agricultural technology does not rule out the adoption of the other available technology since the effects of certain technologies could be complementary; (iii) the adoption of some technology components could be independent due to the variable needs and conditions of producers [3,11,39].

Intensity of adoption is measured in terms of a count variable representing the number of technologies adopted [43]. The number of technologies adopted was categorized, i.e., 0–4 were regarded as low-level adopters, 5–8 as mid-level adopters and >9 as high-level adopters. The categories were assigned integer values 1, 2 and 3, respectively, and used as the dependent variable in the ordered probit model [35].

Therefore, level of adoption (Y_j) is given by:

$$Y_j = \begin{cases} 1\ if\ 0 < y_j \leq 4 \\ 2\ if\ 4 < y_j \leq 8 \\ 3\ if\ 8 < y_j \leq 12 \end{cases} \qquad (y \text{ is the number of technologies adopted}) \tag{5}$$

Since the dependent variable was measured as an integer which is considered count data, Poisson regression models were deemed appropriate. However, the study did not assume equal probability of adoption of each alternative banana technology but rather assumed that the likelihood of adopting the first practice might differ from that of adopting additional others [44].

3. Results and Discussions

3.1. Description of the Household and Farm Characteristics (Dependent Variables)

Our results show that the average family size for low- and mid-adopter households was six household members compared to high-adopter households which consisted of seven members. This indicates the availability of labor associated with the adoption of more new technologies [45]. Although the majority households across adopter categories reported farming as their major source of income, less than 50% grew bananas for commercial use, for example, 36% of low adopters, 44% of mid-adopters and 49% of high adopters (Table 1). In this study, it is expected that high-adopter households which grow bananas for commercial use will adopt more yield-enhancing technologies such as the use of hybrid banana varieties. The study findings suggest that low-adopter households accessed more land (1.87 ha) and allocated a smaller proportion of 0.43 ha to banana production (Table 1) compared to other adopter categories. This implies that low-adopter households could be engaged in other livelihood economic activities other than agriculture, specifically, banana production. The majority of high-adopter households (68%) were located in the dry corridor of Nakaseke and Birere compared to 62% mid- and 64% low-adopters. The high adoption intensity among households in the dry corridor could be associated with the uptake of many technologies, especially those related to soil and water conservation. On the other hand, Rwimi is located near Rwenzori Mountain which positively influences the climatic conditions of the area [31] to support banana production with less investment in soil and water conservation practices.

The results show that only 18% of low-adopters, 25% of mid-adopters and 33% of high-adopter households perceived the fertility status of their soil as high (Table 1). The highest percentage (67%) of high-adopter households had access to formal sources of credit compared to 56% mid and 30% low-adopter households. Access to credit facilitates the acquisition and adoption of technologies which require high capital investment [46]. The results further reveal that only 29% of high adopters, but 18% of mid and low adopters were able to access markets apart from gate and or local markets. However, only a handful of households belonged to farmer groups, for example, 9% of ow-adopters, 37% mid-adopters and 50% high-adopter households (Table 1).

3.2. Description of Banana Technologies Used by the Farming Households (Independent Variables)

The basic banana technologies (de-trashing, de-suckering, corm removal and male bud removal) were implemented by over 80% of low adopters, 97–100% mid-adopters and 100% high adopters. Conversely, the use of inorganic fertilizers and banana hybrids were new technologies and implemented by none of the low adopters, maximum of 7% among mid-adopters and only 14% of high adopters. Other than sterilizing tools, the rest of the technologies were implemented by less than 10% of low adopters, above 15% mid- and a minimum of 40% high adopters (Table 2).

Table 2. Description of banana technologies used by the households.

		Percentage Households Using the Practice		
Basic Mat Maintenance Practices	**Variable Description**	**Low Adopters (n = 33)**	**Mid Adopters (n = 208)**	**High Adopters (n = 92)**
De-trashing	1 if practiced and 0 if not	91	99	100
De-suckering	1 if practiced and 0 if not	85	99	100
Corm removal	1 if practiced and 0 if not	82	97	100
Male bud removal	1 if practiced and 0 if not	94	100	100
Pests and disease control practices				
Clean seed (corm paring/use of tissue culture plantlets)	1 if practiced and 0 if not	0	6	43
Sterilizing garden tools	1 if practiced and 0 if not	15	67	88
Weevil trapping	1 if practiced and 0 if not	0	35	70
Planting banana hybrids	1 if practiced and 0 if not	0	7	46
Herbicide use	1 if practiced and 0 if not	3	15	40
Soil and water conservation practices				
Mulching	1 if practiced and 0 if not	9	39	65
Trench digging and desilting	1 if practiced and 0 if not	0	47	86
Basin digging and desilting	1 if practiced and 0 if not	0	16	43
Use of organic manure	1 if practiced and 0 if not	3	39	83
Use of inorganic fertilizers	1 if practiced and 0 if not	0	2	14

3.3. The Nature of Relationships among Multiple Banana Practices

The study findings from MVP analysis indicate that households adopted multiple banana technologies simultaneously, suggesting associations among them. This was tested using pairwise correlation coefficients across the residuals of MVP model. Of the 36 pairs among nine banana technologies, 15 pairwise correlation coefficients were statistically significant. The results support the hypothesis that error terms of the multiple adoption decision equations are correlated. The likelihood ratio test (Chi^2 (36) = 184.274; Prob > chi^2 = 0.000) rejects the null hypothesis of zero covariance of the error terms across the equations. Such results indicate that banana technologies are adopted as complements and substitutes as indicated by the 15 significantly correlated pairs. It also implies that households may adopt a combination of input intensification and low-external-input banana technologies. This is in agreement with other studies which recognized the interdependence of adoption decisions of multiple agricultural technologies [12,39].

3.4. Determinants of Adoption Patterns for Banana Technologies

The results show that household size was positively and significantly associated with the adoption of trenches ($p < 0.05$) and use of banana hybrid varieties ($p < 0.1$) (Table 3). This indicates that households with a larger number of members are more likely to adopt the use of trenches and banana hybrid varieties. These technologies are often labor-intensive, hence the increased probability of being adopted by larger households, given the high dependency on family labor in the study area. According to Okuthe [47] and Akankwasa et al. [22], family size plays a significant role in enhancing the adoption of labor-intensive agricultural technologies.

Table 3. Determinants of adoption patterns for banana technologies.

	Banana Technologies (n = 333)								
Independent Variables	**Mulch**	**Herbicide**	**Manure**	**Clean Seed**	**Trench Desilt**	**Basin Desilt**	**Sterile Tools**	**Weevil Trapping**	**Hybrid Varieties**
Socioeconomic characteristics									
Gender of household (hh) head	−0.060 (0.265)	0.372 (0.323)	−0.255 (0.244)	0.086 (0.334)	0.002 (0.245)	0.258 (0.292)	−0.374 (0.255)	0.432 * (0.245)	0.077 (0.279)
Household size	0.027 (0.027)	0.000 (0.030)	0.027 (0.027)	0.056 (0.036)	0.062 ** (0.027)	0.002 (0.031)	0.020 (0.026)	−0.010 (0.026)	0.059 * (0.031)
Hh experience growing bananas	−0.011 (0.007)	−0.008 (0.007)	−0.008 (0.006)	0.003 (0.008)	−0.021 *** (0.006)	0.003 (0.006)	0.006 (0.006)	0.003 (0.006)	−0.004 (0.007)
Hh income source	0.264 (0.289)	0.320 (0.315)	0.047 (0.280)	−0.897 *** (0.316)	0.599 ** (0.280)	0.041 (0.298)		0.367 (0.266)	−0.511 * (0.282)
Why they grow bananas	0.014 (0.162)	−0.014 (0.174)	−0.137 (0.153)	−0.169 (0.196)	0.096 (0.153)	−0.143 (0.171)		0.225 (0.147)	0.216 (0.179)
Physical farm characteristics									
Log land accessed (ha)	−0.157 (0.128)	−0.055 (0.140)	−0.222 * (0.121)	−0.013 (0.156)	−0.130 (0.124)	−0.235 * (0.142)	−0.203 * (0.120)	−0.071 (0.121)	0.124 (0.141)
Log Total banana area (ha)	0.288 ** (0.144)	−0.100 (0.144)	0.388 *** (0.130)	−0.024 (0.170)	0.324 ** (0.131)	0.337 ** (0.151)	0.370 *** (0.128)	0.178 (0.129)	−0.384 *** (0.146)
Physical location	−0.368 ** (0.155)		0.002 (0.147)	−0.282 (0.196)	0.130 (0.150)	−0.140 (0.166)	0.097 (0.149)	0.110 (0.143)	−0.108 (0.172)
Soil fertility status 1	−0.124 (0.216)	0.338 (0.235)	0.227 (0.203)	0.772 *** (0.279)	0.217 (0.202)	−0.488 ** (0.243)			0.253 (0.195)
Soil fertility status 3	0.050 (0.185)	0.328 (0.203)	−0.008 (0.170)	0.399 * (0.230)	−0.024 (0.170)	0.062 (0.186)			
Ecological location	−1.147 *** (0.175)	0.577 *** (0.193)	0.444 ** (0.172)	0.822 *** (0.241)	0.234 (0.163)	0.439 ** (0.194)	0.030 (0.156)	−0.082 (0.155)	0.536 *** (0.202)

Table 3. *Cont.*

	Banana Technologies (n = 333)								
Independent Variables	**Mulch**	**Herbicide**	**Manure**	**Clean Seed**	**Trench Desilt**	**Basin Desilt**	**Sterile Tools**	**Weevil Trapping**	**Hybrid Varieties**
Access to agricultural support services									
Contact with extension		−0.134 (0.424)		3.989 (95.542)		−0.316 (0.418)		−0.069 (0.335)	
Membership to farmer group	0.398 ** (0.163)	0.541 *** (0.177)	0.182 (0.158)	0.122 (0.202)	0.344 ** (0.158)	0.171 (0.177)	0.060 (0.154)		0.098 (0.186)
Access to formal credit sources	0.153 (0.166)	0.191 (0.187)	0.062 (0.156)	0.526 ** (0.214)	−0.017 (0.158)	−0.058 (0.178)	0.157 (0.156)	0.146 (0.147)	0.432 * (0.194)
Type of input/output market		0.378 * (0.192)	0.142 (0.176)	0.494 ** (0.213)	0.083 (0.176)	0.008 (0.197)			0.314 (0.191)
Distance to the market			−0.004 (0.015)	−0.029 (0.021)					−0.023 (0.017)
Constant	0.208 (0.704)	−3.093 *** (1.173)	0.119 (0.659)	−10.005 (191.088)	−1.035 (0.665)	−0.786 (1.154)	1.006 * (0.601)	−1.297 (0.908)	−2.124 *** (0.733)

Log likelihood = −1506.09; Wald chi^2 (121) = 263.2; Prob > chi^2 = 0.0000. *, **, and *** indicate statistical significance at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively; standard errors are indicated in parentheses.

The findings show that farming as a source of income positively and significantly influenced the use of trenches ($p < 0.05$), and negatively influenced the use of clean seed ($p < 0.01$) and banana hybrid varieties ($p < 0.1$). This implies that households whose source of income was farming were more likely to adopt the use of trenches but less likely to take up the use of clean seed and banana hybrid varieties at the same time. This pattern could be associated with the competing costs and labor requirements to implement the three practices. Other authors, in [26], found that farming as a major source of household income is not enough to provide capital investment into the timely purchase of farm inputs such as clean seed, hybrid varieties and hiring the labor. Thus, given the restricted resources, households whose major source of income is farming prioritize investment in soil and water conservation measures (trenches) using family labor other than disease control practices such as clean seed and hybrid varieties which require cash investments.

The results further reveal that a unit increase in land accessed significantly influenced the household's negative decision to adopt the use of organic manure ($p < 0.1$), basins ($p < 0.1$) and sterilizing tools ($p < 0.1$) (Table 3). This means that households who accessed more land were less likely to adopt the use of organic manure, basins and sterilizing tools. It implies that households who accessed more land could be involved in other farming activities other than banana production. It could also suggest that even if such households practiced banana farming, they may only be focused on implementing the basic banana maintenance technologies other than organic manure, use of basins and sterilizing tools which require capital and labor investment. As expected, a unit increase in land allocated to bananas significantly increased the probability of adopting banana technologies in a pattern involving several soil and water conservation practices such as mulching ($p < 0.05$), use of organic manure ($p < 0.01$), use of trenches ($p < 0.05$) and basins ($p < 0.05$). The increase in the size of the banana plantations also increased the household's probability to sterilize tools ($p < 0.01$). Banana technologies are applied in already established plantations. Therefore, the bigger the size of the plantation available, the higher the number and coverage of technologies applied as shown in these results. On the contrary, a unit increase in the land allocated to bananas was significantly and negatively associated with the adoption of hybrid banana varieties ($p < 0.01$). This was expected because while the rest of the banana technologies and practices are applied in already-established plantations, the use of hybrid varieties requires opening up of new gardens which may not be available.

Households located in the dry corridor (Nakaseke and Birere) were more likely to adopt technologies in a pattern involving input intensification (herbicides ($p < 0.01$), clean seed ($p < 0.01$), and hybrid banana varieties ($p < 0.01$)) and low-external-input technologies, especially those associated with soil and water conservation (organic manure ($p < 0.05$), and basins ($p < 0.05$)). Birere and Nakaseke experience long dry spells which compel farmers to adopt most of the soil and water conservation practices they get exposed to. In addition, the farmers in these areas are commercially oriented, focusing on banana enterprise because of the relative advantage they have over other areas to access the market. In Birere, for example, banana has been a sole cash and food crop for a long time [40] because of the crop's tolerance to drought conditions [48], while Nakaseke's strategic location near major towns in Uganda offers a ready market for the produced bananas. Therefore, the farmers in Nakaseke and Birere are motivated to take up banana technologies to greatly improve and maintain banana productivity. On the other hand, households in these areas were less likely to use mulch ($p < 0.01$) because of the presence of termites which destroy the organic mulches in a short time. They also indicated that being in a dry corridor predisposes their plantations to fire hazards; thus, they choose not to mulch.

Household membership to a farmer group was positive and significantly related to the adoption of mulches ($p < 0.05$), herbicides ($p < 0.01$) and the trenches ($p < 0.05$). This could be a result of formal and informal interactions among the group members which enable them to exchange information and services, harmonize their beliefs and attitudes, and overcome resource constraints such as labor and capital investments related to the adoption of new technologies [3]. In addition, some farmer groups are initiated by extension and development organizations to enable for them easy outreach and dissemination of agricultural technology and information to the farmers [49]. Thus, banana farming households who belong to farmer groups have access to adequate information with regard to the use of banana technologies to enable them to adopt a technological package in a pattern involving more technologies.

The study also shows that access to formal sources of credit has a significant positive effect on the adoption of banana technologies in a pattern involving the input intensification technological package of clean seed ($p < 0.05$) and hybrid varieties ($p < 0.1$). Credit access provides the farmers with alternative cash sources to purchase the clean seed and pay for the labor requirements to grow banana hybrids. This conforms with the study by Okuthe [47] who found that money availability and access to credit had a positive effect on the use of improved seed varieties and associated practices in integrated natural resource management.

Household access to input and output markets in major towns of Uganda was positively associated with the use of herbicides ($p < 0.1$) and clean seed ($p < 0.05$). These markets offer better prices and various options leading to the farmers' enhanced returns to invest in the adoption of technologies which require a relatively high capital investment. Thus, such households benefit from the favorable prices which would otherwise be impossible with the acquisition of inputs in local markets or the sale of bananas at a farm gate. A recent study by Mujeyi et al. [50] also reported that farmers were more likely to adopt technologies whose products have alternative markets which offer better prices and higher income earnings than there would be at the farm gate.

3.5. Determinants of the Adoption Intensity of Banana Technologies

The maximum number of banana technologies adopted by a particular household was 12, implying that none of the households had adopted all the 14 promoted banana technologies. Hence, there is still potential to increase the adoption intensity of banana technologies.

Household size, total area under bananas, soil fertility status, ecological location, household membership to a farmer group, access to formal sources of credit, and input and output markets in major towns of Uganda had significant effects on the adoption intensity of banana technologies (Table 4). Moreover, these same variables produced significant results with the MVP model (Table 3). This indicates that the variables greatly affect household adoption decisions involving multiple agricultural technologies and practices. Worth noting, the effects of these variables were similar and negative among low adopters (0–4 technologies) and mid-adopters (5–8 technologies), but positive among high adopters

(9–12 technologies). In addition, the magnitude of negative influence was higher among low-adopter households than in mid-adopters, while for high adopters, the magnitude of positive influence was almost the summation of the magnitude of low and mid-adopters (Table 4). Teklewold et al. [51] suggest that an increase in magnitude indicates that the number of households adopting several technologies increases with the increasing number of technology options available. Thus, the results of this study imply that the greater the number of banana technologies available in a package, the greater the increase in the number of adopting households.

Table 4. Factors that influence the adoption intensity of banana technologies among the households.

		Marginal Effects		
Variables	**Coefficients**	**Low-Level Adopters**	**Mid-Level Adopters**	**High-Level Adopters**
Socioeconomic characteristics				
Gender of household (hh) head	0.225 (0.248)	−0.035 (0.039)	−0.033 (0.036)	0.068 (0.074)
Household size	0.047 * (0.026)	−0.007 * (0.004)	−0.007 * (0.004)	0.014 * (0.008)
Hh experience growing bananas	−0.006 (0.006)	0.001 (0.001)	0.001 (0.001)	−0.002 (0.002)
Marital status of the hh head	−0.241 (0.200)	0.038 (0.032)	0.035 (0.029)	−0.073 (0.060)
Age of the household head	−0.002 (0.006)	0.000 (0.001)	0.000 (0.001)	−0.001 (0.002)
Why they grow bananas	−0.055 (0.144)	0.009 (0.022)	0.008 (0.021)	−0.017 (0.043)
Physical farm characteristics				
Log land accessed (ha)	−0.087 (0.110)	0.014 (0.017)	0.013 (0.016)	−0.026 (0.033)
Log Total banana area (ha)	0.233 ** (0.115)	−0.036 ** (0.018)	−0.034 * (0.017)	0.070 ** (0.034)
Soil fertility status 1	0.420 ** (0.189)	−0.066 ** (0.030)	−0.061 ** (0.028)	0.127 ** (0.056)
Soil fertility status 3	0.107 (0.160)	−0.017 (0.025)	−0.016 (0.023)	0.032 (0.048)
Ecological location	0.280 * (0.158)	−0.044 * (0.025)	−0.041 * (0.023)	0.085 * (0.047)
Access to agricultural support services				
Contact with extension	0.493 (0.323)	−0.077 (0.050)	−0.072 (0.049)	0.149 (0.097)
Membership to farmer group	0.433 *** (0.147)	−0.068 *** (0.024)	−0.063 *** (0.023)	0.131 *** (0.043)
Access to formal credit sources	0.266 * (0.144)	−0.042 * (0.023)	−0.039 (0.022)	0.080 * (0.043)
Type of input/output market	0.318 * (0.163)	−0.050 * (0.026)	−0.046 * (0.024)	0.096 ** (0.049)
Distance to the market	−0.024 (0.016)	0.004 (0.003)	0.004 (0.002)	−0.007 (0.005)
Log transport cost to the market	0.067 (0.053)	−0.010 (0.008)	−0.010 (0.008)	0.020 (0.016)
/cut1	1.150			
/cut2	3.242			

LR chi^2 (17) = 50.2; Prob > chi^2 = 0.0000). *, **, and *** indicate statistical significance at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively; standard errors are indicated in parentheses.

The results show that having a larger household increased the propensity to adopt more than eight technologies by 1.4% (Table 4). This is attributed to the availability of relatively cheap family labor to engage in practicing several technologies and practices. In addition, larger households are motivated to take up more technologies to boost productivity and meet household food consumption requirements [50,51]. Therefore, adoption of more than eight banana technologies among large households could be attributed to the desire to produce enough food for household consumption.

An increase in the household land allocated to bananas increased the tendency to adopt more than eight technologies by 7%. Other than a few technologies such as the use of hybrid varieties, most of the banana technologies are applied in an already established plantation. Therefore, the more land covered by the plantation, the more likelihood of using more technologies.

If a household was located in the dry corridor, the propensity of adopting more than eight technologies increased by 8.5%. This could be attributed to the increased adoption of soil and water conservation technologies to reduce the effect of drought on the bananas [48].

Membership to a farmer group increased households' propensity to adopt more than eight banana technologies by 13.1%. This could be attributed to the ability of the groups to facilitate timely access to the necessary information, inputs and labor requirements for the adoption of more technologies [50]. Increased access to formal sources of credit increased the propensity to adopt more than eight technologies by 8%. This is due to the increased access to alternative financial support services to invest in the adoption of more technologies. Similarly, increased access to the input and output markets in major towns of Uganda increased the adoption of more than eight technologies by 9.6%.

4. Conclusions and Policy Implications

Banana farming households adopted technological packages in patterns involving combinations of input intensification and low-external-input technologies as complements or substitutes. The complementarity of technologies implies the promotion of such technologies as a package of options rather than, in isolation, which strategy presents more options that can maximize the benefits from such synergies. Adoption intensity results obtained from estimating the ordered probit model revealed that farmers had a tendency of adopting more technologies. The propensity to adopt was bigger among high adopters (9–12 technologies) than in mid (5–8 technologies) and low adopters (0–4 technologies). Household size, total banana area, ecological location, household membership to a farmer group, access to formal sources of credit, and input and output markets in major towns of Uganda produced significant results with the MVP model and ordered probit model. This shows that the probability and the extent of adoption are determined by similar factors which should be taken into account when designing adoption interventions for multiple agricultural technologies.

The policy implications for this study for the adoption of multiple banana technologies, in a country such as Uganda where there is limited access to agricultural support services such as extension, labor, and input and output markets, are that farmer groups can play an important role in filling the gap and bringing services closer to the members. With the increased awareness about the technologies, labor availability, and access to the markets through farmer groups, there is increased probability of adopting a full package of technologies leading to improved productivity. Equally important is the association of credit accessibility from formal sources and the use of input intensification technologies (clean seed and hybrid varieties), which implies the need to expand credit delivery systems when promoting the adoption of multiple agricultural technologies.

This study contributes to the existing literature by highlighting the key variables which affect the probability and intensity of adopting technological packages involving both input intensification and low-external-input technologies in Uganda. However, more research should be conducted to establish the effect of adoption patterns and intensity on banana productivity in order to ascertain the efficient use of inputs and technologies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su142315986/s1. Supplementary material is a household survey tool used to collect data for this study. The household survey tool was used to collect data with regards to the physical farm characteristics, household characteristics and the technologies adopted.

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