frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 04 June 2024
DOI 10.3389/fsufs.2024.1339008

OPEN ACCESS

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RECEIVED 15 November 2023
ACCEPTED 29 April 2024
PUBLISHED 04 June 2024

CITATION
Asante BO, Osei MK, Bediako KA, Annor B, Gyau J, Adomako J and Prempeh RN (2024) Improved nursery practices and farmers' willingness to adopt heat-tolerant tomatoes under tropical conditions.
Front. Sustain. Food Syst. 8:1339008.
doi: 10.3389/fsufs.2024.1339008

Improved nursery practices and farmers' willingness to adopt heat-tolerant tomatoes under tropical conditions

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Heat-tolerant tomato (*Solanum lycopersicum* L) can be used to alleviate the impact of climate variability, increase productivity, and increase income of smallholder vegetable farmers under tropical conditions. Adoption of improved nursery practices and willingness to adopt heat-tolerant tomato varieties under tropical conditions was examined. Using data from 432 tomato farmers, multivariate probit and tobit regression models were used to assess willingness to adopt heat-tolerant varieties and number of nursery practices. Willingness to adopt heat-tolerant tomato varieties was positively influenced by education, experience, and extension contacts. Adoption of improved nursery practices was influenced by sex, household size, off-farm income, credit, education and extension. These results will enable decision-makers to prioritize strategies that target educated farmers with more years of experience in tomato production and have contacts with extension to enhance the adoption of heat-tolerant tomato seeds with complementary improved nursery practices to increase productivity and income of smallholder tomato farmers under tropical conditions.

KEYWORDS

***Solanum lycopersicum*, climate variability, multivariate probit, tobit model, Ghana**

Introduction

Erratic nature of rainfall pattern has resulted in highly seasonal nature of tomato (*Solanum lycopersicum* L.) production (Robinson and Kolavalli, 2010). This results in high price, high demand, and fluctuating output which have serious implications for income of smallholder farmers. Production mainly depends on family, rented, or land of relatively small sizes (less than 2 acres; Monney et al., 2009). In spite of the importance of improved seed in improving yield, smallholder farmers in Ghana still cultivate local varieties (Robinson and Kolavalli, 2010; FAO, 2016). Varieties commonly grown in Ghana include Roma VFN, Pectomec VF, Tropimec, Rion Grande, Jaguar, Lindo, Titao Derma, Ada Cocoa, Laurano, Raki, Choco TP, Power Reno, Rasta, and Italy Heinz (Ministry of Food and Agriculture (MoFA), 2010; FAO, 2016). Farmers tend to accept, and adopt, recommended varieties and practices due to yield benefits, matching with existing farming system, and simple to use (Al-Shadiadeh et al., 2012; Danso-Abbeam et al., 2012).

Farmers are more inclined to accept, and adopt, recommended varieties and practices due to yield benefits when compared with existing varieties (Al-Shadiadeh et al., 2012; Danso-Abbeam et al., 2012). The rate of adoption of a technology depends on the characteristics of individual farmer's production circumstances, characteristics of technology, socioeconomic characteristics of farmers, and speed with which the population is made aware of the technology and its application to local production systems (Siziba et al., 2011; Etwire et al., 2013; Xaba and Masuku, 2013; Sanusi and Dada, 2016). Improved nursery practices in tomato production are necessary to increase vigor, growth, and efficient productivity (Thakur and Tripathi, 2015; Easdown and Ravishankar, 2016). However, the adoption of these practices is low among local smallholder tomato producers (Ministry of Food and Agriculture (MoFA), 2016). Promoting adoption of improved nursery practices is important for efficient production. However, the adoption of these practices is low among smallholder tomato producers (Ministry of Food and Agriculture (MoFA), 2016).

Studies have examined the adoption of improved production practices (Asante et al., 2013; Huat et al., 2013; Masood et al., 2018; Frimpong et al., 2021; Gotame et al., 2021; Nkansah et al., 2021; Shrestha et al., 2021; Iqbal et al., 2022; Akomdo et al., 2023). Most of these studies focused on the agronomic effects (Masood et al., 2018; Gotame et al., 2021; Shrestha et al., 2021; Iqbal et al., 2022), while others investigated such adoption decisions under different production settings. For instance, Nkansah et al. (2021) examined the influence of topping and spacing on growth, yield, and fruit quality of tomato under greenhouse condition. Frimpong et al. (2021) examined the relationship between sociodemographic, institutional factors, and adoption of best tomato production practices in Southern Ghana. However, the study focused on the relationship between such factors, without any attempt in estimating the determinants of adoption of these practices. To the best of our knowledge, a study examining farmers' adoption of improved nursery practices and their willingness to adopt improved heat-tolerant tomatoes under tropical conditions has not been explored. This study examines this nexus and investigates the willingness decision of rural tomato farmers to adopt heat-tolerant tomato varieties under tropical conditions and provide vital policy insights for enhancing the tomato industry, especially in the midst of climate variability in order to enhance the welfare of rural farmers.

Thus, the findings of this study present a better understanding of the underlying factors, influencing low adoption, and presents useful insights into guiding policy for enhancing local tomato production. Given that farmers in Ghana still produce local varieties, the findings also present an opportunity to develop locally adapted improved varieties that are high yielding and tolerant to biotic and abiotic stresses, to meet the increasing demand for the fruits both for local industry and fresh consumption.

This study examines the drivers of adoption of improved nursery practices and estimates farmers' willingness to adopt heat-tolerant tomato varieties in Ghana. We contribute by providing empirical evidence on the drivers of adoption of improved nursery practices for enhancing policies to improve tomato production in Ghana. Such information is essential for the tomato sector because of the vital role nurseries play in open field production and its implications in the entire tomato value chain. In addition, our result provides empirical insights of the factors influencing farmers' willingness to adopt heat-tolerant tomato varieties. Such information is essential for research on crop movement programs, especially tomato breeders in the development of improved varieties with such attributes as part of the characteristics to consider. Finally, the findings will provide useful insights for policymakers in designing agricultural policies aimed at enhancing the adoption of improved nursery practices and heat-tolerant varieties for improving tomato production in the country to meet local demand for consumption and processing.

The rest of the study is structured as follows. The next section presents the methodology which includes a description of the study area, data, sampling, and the empirical strategy for the analyses. The next section presents the results and discussions, and the final section presents the conclusions and policy recommendations.

Methodology

Study area

Basically, Ghana has six agroecological zones with various ranges of climatic, vegetation, and soil types. These zones are categorized into tropical rainforest, semi-deciduous forest, forest savannah transition, coastal savannah, Guinea savannah, and Sudan and Sahel savannah. Thus, the study was conducted across four out of the six major agroecological zones, namely, Guinea savannah, forest savannah transition, coastal savanna, and the Deciduous Forest agroecological zones.

The Deciduous rainforest, forest savannah transition, and costal savannah zones are characterized by bimodal rainfall pattern, resulting in major and minor cropping seasons. Mostly, forest savannah transition and deciduous forest agroecological zones cover the Bono, Ahafo, and Ashanti regions with an exceptional environment that is favorable to the production of various crops and livestock (Ghana Districts Repository, 2020). Averagely, the zones recorded annual rainfall between 1,200 and 1,400 mm and temperature of 25°C with favorable climatic and social factors that boost the cultivation of huge volume of crop varieties (Ministry of Food and Agriculture (MoFA), 2019).

In the Guinea savanna zone, approximately 80% of the land in the forest- savanna transition region is used for crop and livestock production. The zone records a unimodal rainfall pattern, resulting in a single growing season and enhancing several crops thrives well in this zone such as tomato, maize, rice, cowpea, groundnuts, and yam cassava. Across the four agroecological zones, tomato production is a major economic activity in the resident population.

Data were collected from the Offinso, Techiman, and Tano South districts in the Bono and Ahafo regions under the forest transition agroecological zones. In addition, the Asante Akim Agogo and the Mampong districts under deciduous forests, Kassena-Nankana district under Guinea savanna, and Ada West and Agotime districts under coastal savannah were involved. These districts were selected because they are the important for tomato production in the country. The majority of the tomato produced in Ghana can be traced from these districts.

Data and sampling

A multi-stage sampling technique was employed to sample and interviewed 432 smallholder tomato farmers. In the first stage, the four agroecological zones, namely, forest, transitional, coastal, and Guinea Savannah, were purposively selected based on the prevalence of tomato production and the dominance of tomato producing rural farm households in these agrological zones. From each of the selected agroecological zone, four districts were also purposively selected to reflect the high tomato production trends in the zone. From each district, two tomato producing communities were purposively selected from a list of tomato producing communities. From each community, a maximum of 30 tomato producing households were randomly selected and interviewed using a semi structured questionnaire to obtain the primary data used in this study. Data collected comprised demographic, production, input, and output quantities and prices.

Empirical strategy

Data collected were analyzed and summarized using descriptive statistics, such as frequency, charts, graphs, and tables. To understand the factors influencing willingness to adopt heat-tolerant varieties of tomatoes, the binary probit model was used, while the multivariate probit regression model and tobit models were applied to estimate the factors influencing the adoption of improved nursery practices. These methods are discussed in detail in the following paragraphs.

Examining the factors influencing the adoption of heat-tolerant tomato varieties

To examine the factors influencing the adoption of the nursery practices of tomato farmers, a probit model was used (Rahm and Huffman, 1984). In this case, the utility obtained if they adopt nursery practice is greater than that for non-adopters, i.e., ($U_{i1} > U_{i0}$). This response is a binary one, and the outcomes are mutually exclusive.

The binary probit model

The binary dependent variable, Y_i assumes the values "1" if a farmer is willing to adopt the heat tolerant variety, "*adopter*" and "0" if otherwise. Thus, this is represented as a function of the demographic characteristics and institutional factors X (such as age, sex, years of schooling, household size, tomato experience, number of plots, off-farm income, credit access, extension visits, distant to extension office, FBO membership, and IP membership) and an error term with mean of zero stated in Equations (1) and (2) below:

$$U_{i1}(X) = \alpha_1 X_i + \delta_{i1} \text{ for adopter} \tag{1}$$

$$U_{i0}(X) = \alpha_0 X_i + \delta_{i0} \text{ for non} - \text{adopter} \tag{2}$$

Thus, observing a value of 1 will generate probability,

$$P_r = (Y_i = 1 / x_i \alpha_i) = 1 - H(-x_i \alpha_i) \tag{3}$$

and the probability for observing 0 could be given as follows:

$$P_r = (Y_i = 0 / x_i \alpha_i) = H(-x_i \alpha_i) \tag{4}$$

where H denotes a continuous variable, strictly increasing cumulative distribution function and thus taking a real value and returns a value which ranges from 0 to 1.

Thus, we estimate the parameters in the models in equations (3) and (4) through the maximum likelihood estimation (MLE) procedure. The dependent variable is an unobserved latent variable and is expressed in Equation (5) as follows:

$$Y_i \text{ as } Y_i = \alpha_j X_{ji} + \delta_i \tag{5}$$

where δ_i is a random error term.

The observed dependent variable is determined by whether the predicted Y^* is greater than 1 or otherwise as specified in Equation (6) as follows:

$$Y_i = 1 \text{ if } Y_i^* > 0 \text{ and } Y_i = 0 \text{ if } Y_i^* \leq 0 \tag{6}$$

where $Y_i^*$is the threshold value for $C_i$and is assumed to be normally distributed.

The probit model adopted for the study is expressed in Equation (7) as follows:

$$P_i = P(Y_i^* < Y_i) = P_i = P(Y_i^* < \alpha_0 + \alpha_j X_{ji}) \tag{7}$$

where P_i is the probability that an individual will make an objective decision by adopting "*adopter*" or not adopting "*non-adopter*" and Y_i is the dependent variable.

Estimating the adoption of improved nursery practices in tomato production

The adoption of nursery practices is multivariate in nature, thus adoption of these practices include fertilizer application, hardening, staking, pruning, and soil treatment is such that a farmer will adopt any of these practices or a combination of them that best addresses his/her production needs. In effect, the decision of the farmer whether to choose one or another underlies on information on several other practices available. Subsequently, a farmer is likely to adopt a specific practice if the benefits obtained from adoption are greater than that of non-adoption.

The multivariate probit model

The adoption of nursery practices is modeled along the random utility framework (Kassie et al., 2013; Mulwa et al., 2017). In this case, an i^{th} farmer faced the decision to adopt in a j^{th} practice where $i = 1,2,3......., N$ and $j = 1,2,3....., J$, i.e., j = adoption of nursery practices, such as fertilizer application (FA), staking (SK), pruning (PR), soil treatment (ST), and hardening (HR). Thus, we decide to let P^*signify the difference between the utility from adoption $(U_{iA})$and the utility from non-adoption (U_{iN}) of particular nursery practices. A randomly selected farmer from given household i will decide to adopt a specific nursery practice if $P^* = U_{iA} - U_{iN} > 0$. Accordingly, the benefits from adopting a specific nursery practice are a latent variable, which are determined by the observed covariates (X_i), and the error term (ε_i) is expressed in Equation (8) as follows:

$$P_{ij}^{*} = X_i^{'}\beta_j + \varepsilon_i \quad (8)$$

Therefore, the two utilities are unobservable but can be stated for each nursery practice as a function of observable components in the latent variable, which is expressed in Equation (9) as follows:

$$P_{ij} = \begin{cases} 1 & \text{if } P_{ij}^{*} > 0 \\ 0 & \text{otherwise} \end{cases} \quad (9)$$

Where P_{ij}^{*} is a latent variable that denotes observed and unobserved preferences associated with the j^{th}nursery practice, and P_{ij}denotes binary dependent variables. Xik denotes a set of household and farm-specific characteristics and institutional variables. Aik denotes plot characteristics to account for unobserved heterogeneity. β_k and α_k are estimated parameters. ε_k denotes the multivariate normally distributed stochastic error term (Wooldridge, 2003). Based on the multivariate probit model, the possibility of adopting multiple nursery practices and the error terms jointly follows a multivariate normal distribution (MVN) with zero conditional mean and variance which are normalized to unity, i.e., and the covariance matrix © is given in Equation (10) by:

$$\Omega = \begin{bmatrix} 1 & \rho_{FASK} & . & \rho_{FAHR} \\ \rho_{SKFA} & 1 & . & . \\ . & . & 1 & \rho_{STHR} \\ \rho_{SKHR} & . & \rho_{HRST} & 1 \end{bmatrix} \quad (10)$$

where ρ denotes the pairwise correlation coefficient of the error terms with respect to any two of the estimated adoption equations of the nursery practices. Consequently, the off-diagonal elements (e.g., ρ_{GM}, ρ_{MG}) in the covariance matrix denote the correlation between the stochastic components of the different nursery practices (Mulwa et al., 2017). The non-zero value of these correlations in the off-diagonal elements supports the appropriateness of the use of the multivariate probit model.

Tobit model

The tobit model is used to analyze the joint decision made by tomato farmer. Some factors influence the number of tomato nursery practices adopted by the farmers. For instance, there is a latent unobservable variable Y_i that depends linearly on $X_i$through β_i vector parameters. We have normally distributed error term $e_i$to capture random effects. Considering the dependent variable, Y_i denotes the latent variable whenever the latent variable is above zero and zero otherwise (Sindi, 2008; Chebil et al., 2009). The tobit model used in this study measures the factors influencing the number of tomato nursery practices. The tobit model is expressed in Equations (11)- (13) as follows:

$$Y_i = X_i\beta_i + e_i, e_i = N\left(0, \delta^2\right) \quad (11)$$

$$Y_i = X_i\beta_i + e_i \text{if } X_i\beta_i + e_i > 0 \quad (12)$$

$$Y_i = 0 \text{if } X_i\beta_i + e_i \leq 0 \quad (13)$$

where Y_i denotes dependent variable, X_i denotes independent variable, β_i denotes vector of maximum likelihood estimated coefficients, and $e_i$denotes error term.

Explanatory variables and their *a-priori* expectations

Table 1 presents a description of the explanatory variables used in the model and their measurement and *a-priori* expectations.

Results and discussions

Results

Socioeconomic characteristics of tomato farmers

Socioeconomic characteristics of tomato farmers are presented in Table 1. A typical tomato farmer selected across these zones is on average 44 years. Tomato production is dominated by men constituting 68% with an average of 7.5 years of schooling. The majority of the farmers have completed basic schooling. Characteristically, farmers have 13.5 years of experience in tomato cultivation, implying an in-depth understanding of tomato production with an average farm size of 3.8 acres. Less than half of the farmers representing 36% engaged in off-farm income, obtaining an average of GHS2,190.3 from off-farm income generating activities (Table 2).

In addition, more than half of the farmers (73%) were found to be household heads, while almost half (49%) of them own the land under tomato cultivation.

TABLE 1 Explanatory variables in the multivariate probit model.

Variable	Measurement	Expected outcome
Age	Age of farmer (years)	+
Years of schooling	Years of formal education (years)	+
Number of plots	Number of tomato plots	+
Tomato experience	Number of years of farming tomato	+
Off farm income	Off farm income (GHS)	+/−
Sex	1 = Male, 0 = Female	+/−
Distance	Distance to extension office (km)	−
Extension visits	Extension visits (1 = Yes and 0 = No)	+
Access to credit	Access to credit during last year (yes = 1; 0 = No)	+/−
FBO membership	FBO membership (1 = Yes and 0 = No)	+

TABLE 2 Socioeconomic characteristics of tomato farmers across the regions.

Variable	Forest	Transitional	Coastal	Guinea Savannah	Overall	*F*-value
Age (years)	44.4 (11.18)	43.3 (12.37)	43.5 (12.61)	42.8 (12.56)	43.6 (12.14)	0.35
[c]Gender *(Male = 1)*	68% (0.47)	84% (0.37)	62% (0.49)	65% (0.48)	68% (0.47)	3.76***
Years of schooling	6.8 (4.24)	8.8 (3.22)	8.0 (4.39)	6.0 (5.12)	7.5 (4.50)	7.36***
Years of farming tomato	15.5 (8.64)	15.7 (9.55)	12.3 (8.02)	9.3 (7.05)	13.5 (8.68)	9.60***
Farm size (acre)	2.5 (2.44)	3.5 (3.42)	4.7 (4.50)	1.5 (0.58)	3.8 (3.41)	20.32***
[c]Engaged in off-farm income *(Yes = 1)*	25% (0.43)	27% (0.45)	53% (0.50)	25% (0.43)	36% (0.48)	9.70***
Off-farm income (GHS)	2,112.07 (1779.02)	2,868.0 (1999.31)	2,070.4 (1850.5)	1,903.6 (1501.96)	2,190.3 (2117.02)	1.69
Household size	6.6 (2.49)	7.5 (3.52)	7.3 (2.97)	7.4 (3.17)	7.2 (3.0)	2.55**
Economic active HHM	3.5 (1.71)	4.2 (2.42)	3.9 (2.18)	4.0 (1.92)	3.9 (2.10)	3.88***
Dependent HHM	3 (1.8)	3 (1.9)	3 (2.0)	3 (2.0)	3 (1.8)	0.33
[c]Household head *(Yes = 1)*	73% (0.45)	85% (0.36)	70% (0.45)	63% (0.49)	73% (0.44)	2.60**
[c]Land ownership *(Yes = 1)*	49% (0.15)	47% (0.13)	39% (0.11)	44% (0.12)	49% (0.14)	15.99***
[c]Resident status *(Indigenous = 1)*	37% (0.11)	42% (0.12)	39% (0.12)	35% (0.11)	38% (0.12)	1.24
Extension visits (times)	2.8 (2.0)	1.7 (1.0)	2.8 (2.04)	1.7 (2.91)	2.5 (2.07)	7.38***
Distance to nearest extension office (Km)	8.7 (3.56)	8.2 (4.49)	7.0 (4.38)	7.1 (3.06)	7.8 (4.10)	5.21***
Distance to tomato farm (Km)	5.2 (2.36)	5.8 (2.47)	5.1 (2.38)	3.8 (2.19)	5.1 (2.43)	6.29***
[c]Credit access *(Yes = 1)*	11% (0.32)	43% (0.50)	25% (0.44)	16% (0.43)	24% (0.43)	8.55***
Cash amount received for tomato production (GHS)	823.1 (826.79)	2,439.7 (1953.20)	1,534.0 (1400.2)	644.4 (512.71)	1,709.7 (1664.34)	4.85***
[c]Credit payment *(Yes = 1)*	92% (0.28)	89% (0.31)	100% (0.01)	88% (0.01)	94% (0.24)	1.10
[c]FBO membership *(Yes = 1)*	9% (0.29)	41% (0.49)	21% (0.41)	21% (0.41)	22% (0.41)	7.86***
[c]IP membership *(Yes = 1)*	6% (0.24)	5% (0.23)	8% (0.27)	0% (0.01)	6% (0.23)	2.05*
Frequency of cultivation per season	1.0 (0.29)	1.0 (0.26)	1.2 (0.5)	1.0 (0.29)	1.1 (1.08)	6.95***

[c]Dummy variables. Figures in parenthesis are standard deviations. *** 1% significance level; **5% significance level; *10% significance level.

Consequently, a typical tomato producing household comprised of seven members with an average of four of such members being economically active. Thus, these household members provide additional labor to support tomato production, thereby generating more off-farm income for the household. Approximately 38% of the farmers were found to be indigenes, while only 24% of them had access to credit. Surprisingly, farmers received GHS1,709.7 as credit accounting for tomato production, out of which 94% of the them were able to repay the credit received during the year. Again, membership of agricultural groups such as the FBO and Innovative Platform (IP) was very low among the tomato farmers (representing 22 and 6%, respectively) of the farmers across the regions.

Furthermore, it was found out that, on average, typical tomato farmers received three extension visits for which extension officers have to travel an average of 7.8 km to achieve this purpose. Tomato farmers cultivate more than once within the season traveling an average distance of 5.1 km to their farms.

Figures 1, 2 illustrate the distribution of educational level and marital status of tomato farmers across the various agroecological zones. The results showed that educational levels of tomato farmers varied significantly across the various agroecological zones with Pearson chi-square of 74.36 and *p-value* of 0.000. The majority of the farmers who completed basic education were found in the coastal zone (35%), followed by the forest zone with 32% and tradition zone comprising 28%, while Guinea savannah zone recorded the least. In addition, most of the farmers who have completed secondary education are found in the coastal savannah zone constituting 56%, followed by forest and transitional zones representing 15 and 13%, respectively, However, the majority of farmers (33%) in the coastal region have no formal education, followed by Guinea savannah and forest zone constituting 32 and 30%, respectively.

Marital status was found to be differed significantly across the various agroecological zones with Pearson chi-square of 48.05 and *p-value* of 0.000. Mostly, approximately 48% of the farmers were married in the coastal zone followed by 32% in the transitional and 20% in the Guinea savannah zone.

Factors influencing willingness to adopt heat-tolerant tomato varieties among farmers

The probit regression estimates of the factors influencing tomato farmers' willingness to adopt heat-tolerant tomato varieties are presented in Table 3. The results indicate that, household size, household head, years of schooling tomato experience, extension visits, and number of plots cultivated significantly influenced farmers' willingness to adopt heat-tolerant tomato varieties. Both household head and household size negatively and significantly influenced the willingness to adopt decisions. Subsequently, male household heads are less willing to adopt the heat-tolerant tomato varieties than female household heads. Years of schooling positively influenced willingness to adopt heat-tolerant tomato varieties. The result further shows that more years of experience in farming tomato production positively influenced farmers' willingness to adopt heat-tolerant tomato varieties.

Again, extension visits were found to significantly influence farmers' willingness to adopt heat-tolerant tomato varieties. Furthermore, farmers with a smaller number of tomato plots for tomato cultivation are more willing to adopt heat-tolerant varieties.

Factors influencing the adoption of improved nursery practices of tomato production

Table 4 presents the multivariate probit estimates of the factors that influence the adoption of improved nursery practices. The majority of improved nursery practices included in the model are fertilizer application, staking, pruning, soil treatment, and hardening practices.

The result shows that sex showed a positive and significant relationship at 1%. Treatment of soil prevents the soil from disease incidence such as pathogen and fungi, thus adoption of soil treatments has been found to improve and protect the soil inoculant from any kind of harm. Therefore, male tomato farmers are more likely to adopt this practice than female counterparts. Household head negatively and significantly influenced the adoption of staking, soil treatment, and hardening practices at 1, 5 and 1%, respectively. Thus, farmers who are head of the house are less likely to adopt these nursery practices (staking, soil treatment, and hardening practices).

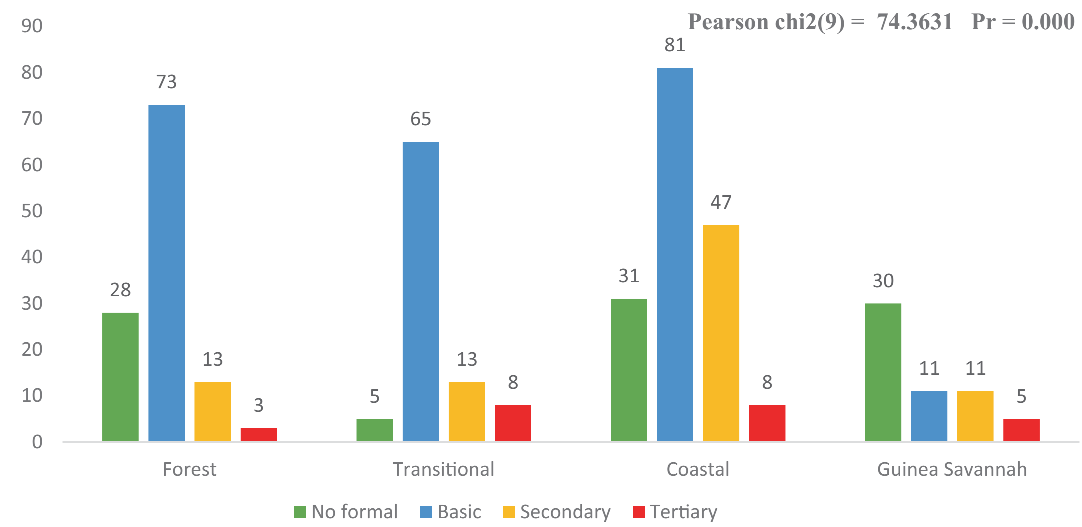

FIGURE 1
Educational level of tomato farmers across the regions.

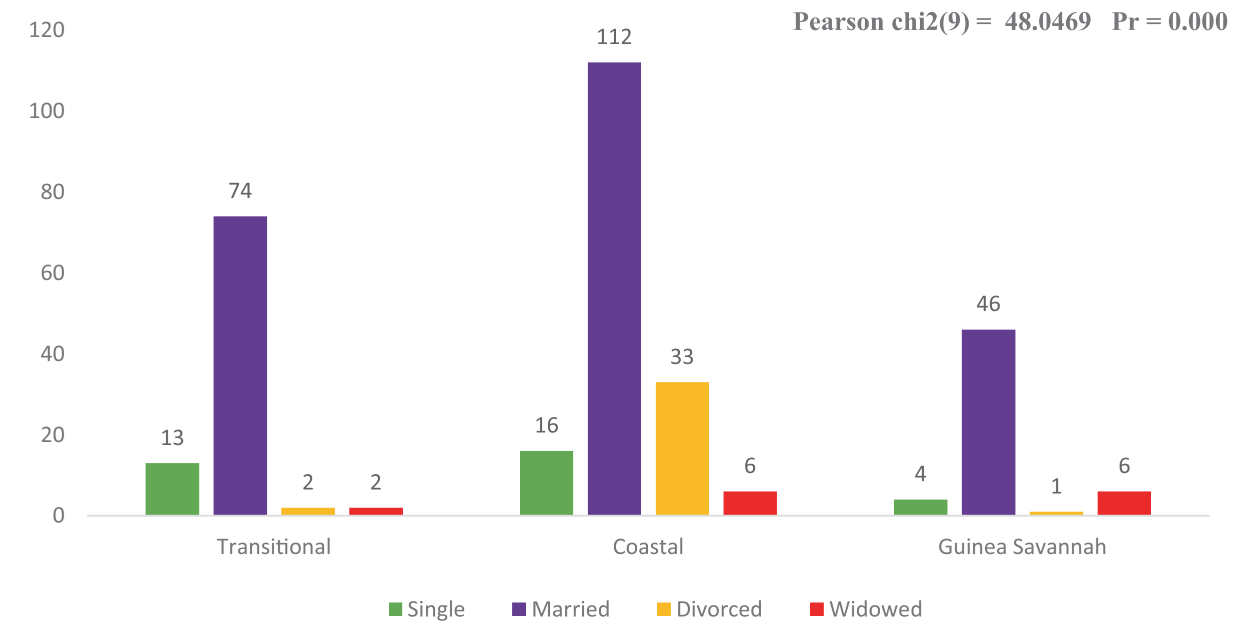

FIGURE 2
Marital status of tomato farmers across the regions.

TABLE 3 Probit estimates of the willingness to adopt heat-tolerant tomato varieties.

WTA	dy/dx	Standard Error	*t*-value
Age	0.010	0.013	0.03
Sex	0.284	0.282	1.01
Household head	−0.634*	0.333	−1.90
Household size	−0.139***	0.040	−3.48
Household member involved tomato cultivation	0.109	0.065	1.68
Years of schooling	0.132***	0.111	−1.19
Tomato experience	0.030*	0.017	1.80
Credit access	0.860	0.357	2.41
FBO membership	0.162	0.323	0.50
IP membership	0.220	0.614	0.36
Distance to extension office	0.026	0.03	0.87
Extension visits	0.116**	0.046	2.50
Number of plots	−0.349***	0.105	−3.33
Constant	2.923***	0.646	4.52
Pseudo r-squared	0.683		
Number of observations	432.00		
Chi-square	33.966		
Prob > chi2	0.000		

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Years of schooling showed a positive and significant relationship between fertilizer application, pruning, and hardening practices. A typical farmer is more likely to adopt these practices due to higher number of years spent in school and ability to adopt new ideas and ways of doing things.

Furthermore, household size positively influenced the adoption of fertilizer application and marginally increased by 12 times at 1% level, while it negatively influenced the adoption of pruning practice significantly at 1% level. In addition, household member involved in tomato cultivation positively and significantly influenced the adoption of fertilizer application and pruning practices at 1 and 5% levels, respectively. Residence status of the farmers was found negatively and significantly influenced the adoption of hardening practice. Thus, the likelihood of adoption of hardening practice was less among indigenes than settlers.

The result shows that key factors influencing the adoption of improved nursery practices are sex, household head, household size, household members involved in tomato cultivation, marital status, credit access, number of plots, number of extension contacts, tomato experience, frequency of cultivation, years of schooling, and membership of innovation platforms. These factors influenced the adoption of various improved nursery practices in different magnitudes.

The variable sex had a positive significant influence only on the adoption of soil treatment before carrying out the nursery function. This implies that men are likely to apply soil treatment in their nursery preparation than women. Because of the economic value of tomato production, men tend to take keen and cautious steps to ensure that the necessary improved practices are adhered to in order to achieve increased productivity.

Being heads of households negatively influenced the adoption staking, soil treatment and hardening among the farmers. Household size and members engaged in tomato cultivation negatively influenced the adoption of both fertilizer application and pruning.

The number of tomato plots cultivated had positive effects on the adoption of three out of the five major practices, namely,

TABLE 4 Multivariate probit estimates of the determinants of adoption of improved nursery practices for tomato production.

Variable	Fertilizer application	Staking practice	Pruning practice	Soil treatment	Hardening practice
Sex	0.438 (0.285)	0.283 (0.238)	−0.188 (0.485)	0.651*** (0.218)	0.421 (0.283)
Age	0.009 (0.008)	−0.003 (0.008)	−0.003 (0.015)	0.010 (0.006)	0.058 (0.053)
Household Head	−0.055 (0.295)	−0.417* (0.232)	−0.686 (0.460)	−0.530** (0.226)	−1.741* (0.961)
Household size	0.121*** (0.040)	−0.036 (0.033)	−0.207*** (0.073)	−0.026 (0.028)	−0.134 (0.232)
Household member involved in cultivation	0.189*** (0.049)	0.065 (0.044)	0.187** (0.073)	−0.005 (0.040)	0.123 (0.149)
Resident status	0.013 (0.249)	0.098 (0.216)	0.213 (0.312)	0.047 (0.178)	−1.844** (0.750)
Marital status	0.020 (0.158)	0.106 (0.146)	0.622** (0.242)	−0.022 (0.123)	−0.235 (0.500)
Off farm income	−0.227 (0.173)	0.255 (0.181)	0.885** (0.348)	0.044 (0.146)	−0.664 (0.739)
Credit access	0.290 (0.211)	0.196 (0.170)	0.496* (0.280)	0.259 (0.166)	0.939 (0.988)
Number of plots	0.004 (0.036)	0.131*** (0.031)	0.034 (0.055)	0.034*** (0.028)	0.215** (0.098)
Extension contacts	0.121*** (0.034)	0.034 (0.031)	−0.007 (0.053)	0.011 (0.029)	0.271* (0.105)
Tomato experience	0.203 (0.137)	−0.132 (0.092)	0.260** (0.114)	0.110 (0.079)	−0.076* (0.044)
Frequency of cultivation	−0.071 (0.263)	−0.379 (0.355)	−0.696* (0.320)	−0.385** (0.180)	6.754*** (0.770)
Years of schooling	0.078*** (0.116)	−0.085 (0.112)	0.400** (0.156)	−0.132 (0.087)	0.390*** (0.205)
FBO membership	−0.005 (0.214)	0.380* (0.205)	−0.232 (0.343)	0.128 (0.176)	−0.092 (1.770)
IP membership	−0.041 (0.363)	0.289 (0.331)	0.329 (0.493)	0.394 (0.341)	9.164*** (2.583)
_cons	0.580 (0.725)	−1.532 (0.716)	−3.784*** (0.942)	1.187*** (0.526)	−6.707 (2.845)
Wald chi2(60)		187.28			
Number of observations		432			
Prob > chi^2		0.000			

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2(6) = 33.2379 Prob > chi2 = 0.0000.

staking, soil treatment, and hardening. Extension visits positively and significantly influenced the adoption of fertilizer application and hardening practices. Experience in tomato production had a positive significant influence on pruning and a negative influence on hardening. Pruning requires consistent practice and some kind of experience to implement it effectively to achieve desired results. Farmers who are members of FBO positively and significantly influenced the adoption of staking practice. Years of schooling positively influenced the adoption of three out of the five improved nursery practices, namely, fertilizer application, pruning, and hardening.

Factors influencing number of nursery practices adopted by tomato farmers

Given the importance of thee improved nursery practices in tomato productivity, to assess the intensity of use, this study further

TABLE 5 Factors influencing the number of nursery practices adopted by tomato farmers.

Nursery practices	Coefficient	Standard error	*t*-value
Age	0.214	0.171	1.26
Economically active HH members	0.11*	0.061	1.79
Year of schooling	0.276**	0.113	−2.44
Off farm income	0.124***	0.034	3.67
Tomato experience	−0.094	0.073	−1.30
Number of Plots	0.095**	0.043	2.19
Farm distance	0.147	0.167	0.88
Credit access	0.074	0.077	0.97
FBO membership	−0.107	0.088	−1.22
IP membership	0.203	0.125	1.62
Farm size	0.011	0.015	0.69
Extension visits	0.003	0.014	0.23
Distance to extension office	−0.021	0.024	−0.85
Frequency of cultivation	−0.249*	0.129	−1.93
Native	−0.111	0.099	−1.12
Guinea savannah	−0.239	0.159	−1.50
Transition	−0.301*	0.167	−1.80
Coastal	−0.374**	0.149	−2.50
Constant	−0.078	0.742	−0.11
Number of observations	432		
Pseudo r-squared	0.307		
Chi-square	41.119		
Prob > chi2	0.001		

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

examines the factors influencing the number of improved nursery practices adopted by the farmers. Table 5 presents the tobit regression estimates of the factors influencing the number of nursery practices adopted by the farmers.

The results show that the key factors influencing the number of improved practices adopted are the number of economically active household members, years of schooling, off-farm income, number of plots, frequency of cultivation, and residing in the transition and coastal savannah agroecological zones. Positive effect was found on the number of economically active household members, year of schooling, off-farm income, and number of tomato plots cultivated, whereas negative effects were found on frequency of cultivation and residing in the transition and guinea savannah agroecological zones.

The number of economically active household members positively influenced the adoption of the number of improved nursery practices adopted by tomato farmers. Years of schooling also had a positive relationship with the number of nursery practices adopted, thus additional year of school results in more nursery practices adopted by tomato farmers. Off-farm income positively and significantly influenced the number of nursery practices adopted by tomato farmers. Thus, farmers are able to channel income from off-farm activities to the adoption of more improved nursery practices and ultimately field tomato production. Farmers who own more plots are more likely to adopt more nursery practices. Farmers with a greater number of plots tend to have available land options for which they need to produce seedlings to cultivate such lands and are more inclined at adopting more improved nursery practices in order to ensure efficient nursery production and obtain the needed quantities of seedlings for cultivating the available plots.

The frequency of cultivation per year had a negative effect on the number of improved nursery practices adopted by tomato farmers, meaning farmers cultivating more cycles or times in a year tend to adopt very few improved nursery practices. Cultivating many times in a year implies spending more resources, including labor, capital and other inputs in the main cultivating hence having less resources and time to adopt more improved nursery practices.

Discussions

Our results reveal that tomato production is dominated by male farmers. This finding agrees who reported that the majority of African agricultural societies have families commonly headed by men. The high marital level of the tomato farmers from our findings implies that the farmers are generally from stable households and are able to explore available family labor for enhancing tomato production. This finding is similar to the study by Defoer (2003) who found that more of the African crop producers are married and live with their families to facilitate the production of their farm crops.

Willingness to adopt heat-tolerant tomato varieties

From our results, the key factors that influence farmers' willingness to adopt heat-tolerant tomato varieties include education, experience in tomato production, extension, and number of plots. Typically, farmers who have attained more years of formal schooling tend to be aware and better appreciate the importance and benefits of heat-tolerant varieties in reducing the impacts of climate variability and are more willingly to adopt such varieties. Similar studies have found a positive effect of education with the adoption of improved nursery practices on tomato production (Al-Shadiadeh et al., 2012; Frimpong et al., 2021; Akomdo et al., 2023).

The positive effect of experience implies that experienced farmers are able to confidently choose among varieties, with their experience tend to be more inclined to varieties that are tolerant to climatic variability and are more willing to adopt heat-tolerant tomato varieties. A strong association was found between experience and the adoption of pre-emergence tomato production practices among smallholder farmers in Ghana. Furthermore, experienced farmers tend to be more enthusiastic and willing to explore new things and are willing to adopt heat-tolerant varieties (Hassan and Nhemachena, 2008; Al-Shadiadeh et al., 2012; Martey et al., 2012).

The positive effect of extension on willingness to adopt heat-tolerant varieties implies that with increased visits by extension agents, farmers are able to receive extension advice, information, and technical support and also are able to participate in extension-related activities which enhance their willingness to adopt heat-tolerant varieties (Al-Shadiadeh et al., 2012; Akomdo et al., 2023). Smaller number of plots are a strategy adopted by smallholder tomato farmers for reducing the risk of crop losses from various sources such as climate variability, enhancing their likelihood of adopting heat-tolerant tomato varieties (Martey et al., 2012).

Adoption of improved nursery practices of tomato production

Major factor influencing the adoption of improved nursery practices included education, household size, and extension visits. Years of schooling showed a positive and significant relationship between fertilizer application, pruning, and hardening practices. This implies that as farmers attain more years of formal education, they tend to be more inclined toward adoption of improved nursery practice. This is because education enlightens the knowledge of the farmers, making them able to read, understand, and appreciate the benefits of adoption of improved nursery practices in order to obtain improved yields. Hence, educated farmers are able to decode and appropriately use improved nursery practices when introduced.

These findings correspond to similar studies (Al-Shadiadeh et al., 2012), indicating that the rate of adoption of a technology tends to be higher with the increasing level of formal education of a farmer. The involvement of a household member adds to the labor used in the farm in terms of these nursery practices to help performing these practices. Larger household size might benefit from being able to use labor resources at the right time and able to adopt more of the practices.

The negative effect of household size and fertilizer application and pruning from the results may be due to the fact that at the nursery stage, these two activities do not require substantial labor. Furthermore, these practices improve aeration and conservation of soil microorganisms, which increases the vigor of the seedlings and ultimately increase productivity of field production. In addition, the cultivation of more plots of tomato, as revealed in our findings, will require additional seedlings for planting, hence influencing the adoption of improved nursery practices. The results are similar to the study by Bezu et al. (2014) and Danso-Abbeam and Baiyegunhi (2017) who found a number of plots and farm sizes to positively influence the adoption of improved technologies.

Extension visits positively and significantly influenced the adoption of fertilizer application and hardening practices; thus, farmers are more likely to adopt these practices and other improved production practices through advice and guidance obtained from extension agents. Consistent with previous studies (Ayandiji and Adeniyi, 2011; Simtowe et al., 2016; Asante et al., 2017; Alhassan et al., 2018; Asante et al., 2021; extension has been found to positively influence the adoption of improved crop production technologies. Farmers are more likely to access to staking information and best staking times through FBO membership. Membership of a farmer association is positively associated with farm size decisions. Thus, tomato farmers belong to FBO benefits from training and other technical supports to enhance tomato production (Chebil et al., 2009; Asante et al., 2011; Kondo et al., 2020).

Increase in years of formal education enhanced the ability of farmers to appreciate the importance of improved nursery practices in enhancing tomato productivity in the field. In addition, farmers are able to appreciate the importance of these practices and better understand them during dissemination techniques by extension agents and other sources. The result are similar to the findings (Enrique and Eduardo, 2006; Alhassan et al., 2018; Baiyegunhi et al., 2019; Barnes et al., 2019; Kondo et al., 2020; Asante et al., 2021), where positive effects were found with education and adoption of improved technologies.

Number of nursery practices adopted by tomato farmers

Major factor influencing the adoption of number of improved nursery practices are number of economically active household members, years of schooling, off-farm income, and number of plots cultivated.

The positive effect of number of economically active persons on the adoption of improved nursery practices implies that an increase in the number of economically active persons in the household results in an increase in the number of improved practices adopted by the farmers. More economically, active household members imply the availability of additional labor or generate additional income to hire extra labor needed for adopting more additional nursery practices in tomato production.

Similarly, the positive effect of years of schooling on the number of nursery practices adopted is consistent with the study by Danso-Abbeam and Baiyegunhi (2017) who reported that longer years of schooling encourage the adoption of technologies among farmers. Furthermore, tomato farmers are able to take better production decisions with better ways of reducing cost (Martey et al., 2012; Asante et al., 2017).

Furthermore, our findings reveal that farmers with more plots are more likely to adopt more improved nursery practices. This finding is similar to the study by Wainaina et al. (2016) who found positive relations with number of plots and adoption of improved seeds and fertilizer in Kenya.

Conclusion and recommendation

This study examined the adoption of improved nursery practices and willingness to adopt heat-tolerant tomato varieties across three agroecological zones in Ghana. The results indicate that tomato production is dominated by men with mean age of 43 years, average of 7.5 years of schooling, and approximately 14 years of experience in tomato production. Most of tomato farmers involved in off-farm income generate activities with a typical household having approximately five members. However, the majority of tomato farmers are not members of farmer-based organization and innovation platforms. The results further indicate that years of schooling, sex, household size, off-farm income, number of plots, extension contacts, credit access, tomato experience, frequency of cultivation, FBO and IP membership, and being in the transition agroecological zone significantly and positively influenced the adoption of tomato nursery practices in Ghana. However, the absence of household head significantly and negatively influenced the adoption of tomato nursery practices.

To enhance the adoption of improved heat-tolerant tomato varieties, the increasing climatic variability will require pragmatic efforts toward improving access to these factors. This should include facilitating access to credit, training through workshop and seminars, and strengthening access to extension services, farmer-based organizations, and innovation platforms. Furthermore, there is a need for stakeholders, especially MoFA, to upscale extension services and strengthen FBOs and IPs among tomato farmers across agroecological zones, to improve the adoption of heat-tolerant tomato varieties in Ghana. In addition, collaboration with local government authorities to facilitate group formation among tomato farmers and guiding and assisting them to identify competitive markets with better bargaining needs to be promoted.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://drive.google.com/file/d/1VE5-YGruEv_JpJAI3VT5JSmfZzSnp8Y4/view?usp=share_link.

Ethics statement

The requirement of ethical approval was waived by the Faculty of Agriculture Review Committee for the studies involving humans because Faculty of Agriculture Review Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) and minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

BOA: Writing – original draft, Methodology, Formal analysis, Conceptualization. MO: Writing – review & editing, Supervision, Project administration, Funding acquisition. KB: Writing – review & editing, Resources. BA: Writing – review & editing, Conceptualization. JG: Writing – review & editing, Investigation, Conceptualization. JA: Writing – review & editing. RP: Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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