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Genebanks and market participation: evidence from groundnut farmers in Malawi

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Abstract

Background: Genebanks contribute to poverty reduction as well as food and nutritional security by being one of the main sources of diversity for the development of improved crop varieties. While the welfare implications of adopting improved varieties have been documented in many rural settings, little attention has been placed on genebanks that often supply key traits and genetic diversity to plant breeders by providing seed samples. In this study, we examined the contribution of the genebank housed by the International Crops Research Institute (ICRISAT) to the development of improved groundnut varieties used by farmers in Malawi. We then related this apportioned genebank contribution to market outcomes, such as market participation and the quantity of groundnut sold in markets.

Methods: Pedigree data obtained through consultations with genebank scientists and breeders were used in combination with a three-wave balanced household-level panel dataset of 447 smallholder farmers in Malawi. Different econometric techniques were used, including a double hurdle model to understand market participation and quantity of groundnuts sold.

Results: We found households to be using six improved groundnut varieties, four of which were traced to the ICRISAT genebank. We analyzed pedigrees of the varieties and apportioned the ancestral contribution of the genebank accessions. Linking the improved varieties grown by farmers with genebank ancestry to market outcomes, we observed a positive association between the ICRISAT genebank and market participation. We could not establish a robust effect on the quantity of groundnuts sold conditional on participation. We found the results to be driven by the area under improved groundnuts.

Conclusion: The ICRISAT genebank has provided accessions that confer useful traits to improved varieties of groundnut adopted by farmers in Malawi. Our analysis indicates that access to genetic resources from genebanks has resulted in the development of improved varieties with traits that are preferred by farmers such as higher yields and resistance to diseases. The adoption of these improved varieties led to increased production surplus and reduced transaction costs, allowing farmers to better participate in local groundnut markets. The study points to the crucial role of genebanks as important sources of crop diversity for improved food security and incomes of smallholder farmers.

Keywords: Genebanks, Market participation, Groundnuts, Improved varieties, Malawi

Introduction

One way to reduce poverty and increase food security in most rural areas is to enhance market participation of smallholders. Market participation not only allows rural households to improve their income and asset streams through crop sales (Muriithi and Matz 2015; Ogutu and Qaim 2019) but may also lead to food and nutrition

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security (Carletto et al. 2017) and livelihood improvements (Ochieng et al. 2020).

In this paper, we study the relationship between the International Crops Research Institute (ICRISAT) genebank and market participation of smallholder groundnut farmers in Malawi. We begin by offering a narrative review of the adoption of the various improved groundnut varieties, where we highlight the advantages and characteristics that make them suitable for consumption and marketing. We then estimate the genebank contribution to each variety, which we derive using pedigree data and expert consultation. We relate the genebank contribution to market participation in a two-step regression framework. In the first step, we assess whether genebank ancestry in the improved varieties grown by farmers significantly affects market participation of smallholder farmers. In the second, we examine the sales intensity of these farmers among those who participate in markets.

To do this, we use a three-wave balanced panel dataset of 447 households in Malawi and apply various econometric techniques. In particular, we use the double hurdle regression approach to model the decision of households to participate in markets and, conditional on participation, estimate the quantity of groundnuts sold. We observe a positive association between the adoption of improved varieties with genebank ancestry and market participation. A similar relationship is observed for the quantity sold, although the findings are not very strong. We find the extent of adoption, defined as the area under improved groundnut cultivation, to be a mechanism through which the ICRISAT genebank contributes to the market orientation of groundnut farmers.

We thus contribute to the empirical literature on market participation and genebank impacts in three ways. First, unlike studies that have established the positive role of the adoption of improved varieties on market participation (Tabe-Ojong et al. 2021a), ours is the first to explore the role of genebanks in such efforts. Of course, understanding the role of genebanks in varietal development is important for food and agricultural policy. Access to the diversity conserved by genebanks contributes to the continual process of developing well-adapted varieties with the special traits needed to address the goals of sustainable development (Bezu et al. 2014; Shiferaw et al. 2014; Verkaart et al. 2017; Tabe-Ojong et al. 2021a). Second, we used panel and pseudo-panel, fixed effect estimators to control for time-invariant unobserved heterogeneity, which enabled us to move closer to causality. Third, our analysis is based on a legume crop (groundnut). Like other legumes, groundnut can be described as pro-poor and environmentally friendly with the ability to stir rural development (Verkaart et al. 2017; Sori 2021; Tabe-Ojong et al. 2021b).

In Malawi as in other countries, households produce groundnuts not only for meeting household food demands but to address other objectives, such as market participation (Tabe-Ojong et al. 2021b). Households may be forward-looking and approach markets as a way of relaxing their liquidity constraints. Entry into groundnut markets in Malawi has been shown to be hindered by high transaction costs and lack of appropriate storage infrastructure. Referring to transaction costs, Katunga et al (2021) found entry into groundnut markets to be positively triggered by informal trader associations. Plausibly, these associations enable increased interaction and collaboration among traders, reducing the costs of gathering information. According to their analysis, institutions, markets and rural infrastructure (roads) are major determinants that drive access to groundnut markets in Malawi. Nyondo et al (2018) highlighted that the groundnut seed market in Malawi is underdeveloped as a result of a weak demand for improved varieties as well as a high seed rate and low seed multiplication ratio. Limited access to improved seeds and the inability of farmers to follow recommended agronomic practices arguably leads to lower yields which limits capacity to participate in markets.

We see two plausible channels through which genebanks can contribute to market participation of smallholder groundnut growers. First, genebanks may contribute to the development of improved varieties that are high-yielding and are less susceptible to various pests, weather extreme conditions, and disease stresses. Increased productivity allows farmers to have production surplus that could be sold in markets, resulting in increased incomes. Second, genebanks may contribute to the development of improved varieties with traits that are preferred both by farmers and consumers. Improved varieties with preferred traits may be more attractive for commercialization, commanding an optimum price and leading farmers to increase the land they allocate to them.

The rest of the article is structured as follows. The “Genebanks and improved groundnut varieties” section provides an overview of the ICRISAT genebank and the various groundnut varieties adopted by farmers in Malawi and their attractive traits. In the “Empirical framework” section, we empirically motivate the analysis and conceptually determine how improved varieties could drive market outcomes. The farm household survey and the pedigree data is discussed in the “Data and variable measurements” section, which is followed by the “Results and discussion” and “Conclusion” sections.

Table 1 Groundnut varieties released in Malawi with ICRISAT pedigree

ICRISAT name	Release name	Year
ICGV-SM83708 (ICGMS42)	Manipintar	1955
	CG7	1990
ICGV-SM 90704	Nsinjiro	2000
JL 24	Kakoma	2000
ICG 12991	Baka	2001
ICGV SM 99568	Chitala	2005
ICGV-SM 08501	CG8	2014
ICGV-SM 8503	CG9	2014
ICGV-SM 01731	CG10	2014
ICGV-SM 01724	CG11	2014
ICGV-SM 01514	CG12	2014
ICGV-SM 99551	CG13	2014
ICGV-SM 99556	CG14	2014

Source: ICRISAT, 2020

Genebanks and improved groundnut varieties

Genebanks serve as repositories for the collection of various types of germplasm of numerous crops and crop wild relatives. Many of these collections are placed in trust with the Food and Agriculture Organization of the United Nations and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) where they are made available for global use for food and agriculture under the Multilateral System (MLS). Most of the international genebanks are housed by the CGIAR. The eleven CGIAR genebanks conserve 736,210 accessions of many food crops, such as legumes, grains, cereals, forages and trees, including banana and root and tuber crops (Genebank Platform 2021). About 94% of the total germplasm distributed by the CGIAR genebanks are sent within the guidelines of the ITPGRFA (Genebank Platform 2021). It is important to highlight that groundnut and its wild relatives are not part of the Annex 1 of the MLS of the ITPGRFA. Global movement of groundnut genetic resources has been significantly restricted and is mainly accomplished by ICRISAT, which is under the Article 15 of the ITGRFA and due to that has all crops conserved in its genebank as part of the MLS. A few national genebanks have also decided to continue their policy of easy access to all germplasm (Bertioli et al. 2020).

We focus on the ICRISAT genebank (<https://genebank.icrisat.org/>), which contains about 50,000 accessions of the grain legumes and pulses, pigeon pea, chickpea, and groundnut and its wild relatives (ICRISAT 2017). Table 1 shows the groundnut varieties released in Malawi and their years of release in that country. Malawian farmers are cultivating six types of groundnuts, identified by

their local names as CG7, Nsinjiro, Kakoma, Baka, Chitala, and Manipintar. In what follows, we look at the traits associated with each of the improved varieties.

There are generally two types of groundnuts grown in Malawi: the Virginia and Spanish types. The Virginia type of groundnut tends to have larger kernel size. The kernel size of the Spanish groundnut is a bit smaller and they are more reddish in colour.

CG 7 (Virginia type), also known as ICGMS 42 or ICGV-SM 83708, is a high-yielding variety, which was released in 1990 and jointly developed by ICRISAT and the Department of Agricultural Research and Technical Services. Recommended for cultivation in all groundnut-growing areas of Malawi, it is suitable for confectionery use and oil extraction (Subrahmanyam et al. 2000). CG 7 is more tolerant to drought and much easier to harvest than other improved varieties. Potential seed yields of CG 7 can reach 2 tonnes/ha, with an average of 0.84 tonnes/ha. Apart from being a high-yielding, medium-duration variety, it is resistant to the groundnut rosette virus. CG 7 is also well adapted to the agro-ecological conditions of the central plateau of Lilongwe and Kasungu. The grain is uniform in size, red, and blanches easily. The plant can take 150 days to mature and is not usually described as late maturing.

Nsinjiro (Virginia type), released as ICGV-SM 90704, is a high-yielding, medium-duration groundnut germplasm that was developed by ICRISAT in Malawi. In collaboration with the National Agriculture Research Systems, it was evaluated in the Eastern and Southern Africa (ESA) region. The variety was then released in 1999 in Uganda as Serenut 2 and a year later in Malawi as ICGV-SM 90704. In the ESA region, it has been widely used, as it is resistant to the rosette virus, although it is susceptible to the aphid vector. Nsinjiro results from a cross between RG1 and Manipintar and was developed following a series of bulk selections for rosette disease reaction using the inferior row technique (Freeman et al. 2002). The variety is very high yielding with an average seed yield of 1.04 tonnes/ha as compared to 0.52 and 0.84 tonnes/ha for Chalimbana and CG7, respectively. Nsinjiro has a low resistance to the rosette virus of 2%, compared to 83% for CG7, and shells at about 67%.

Kakoma (Spanish type), also known as JL 24 (Phule Pragati) is a pure line selected variety from the exotic germplasm EC 94943, which has been released for commercial cultivation. It became a national variety due to its wide adaptability and superior yields and is still popular among farmers across India (Ahire and Khalache 2007). JL 24 was developed in Jalgaon, India, which is one of the important oilseed research stations in Maharashtra (Ingale and Shrivastava 2011). JL 24 was released for commercial cultivation in

Maharashtra and Gujarat in 1979. It is also an early maturing variety, taking about 90–120 days to mature. It is usually advisable to grow when rain events taper off early since it is very susceptible to diseases like rosette and aflatoxin.

Baka (Spanish type), also known as ICG 12991 is a short-duration (90–110 days to maturation), drought-tolerant, Spanish-type peanut with resistance to groundnut rosette disease. ICG 12991 was originally collected from a farmer's field in south India in 1988. In 1994, ICRISAT introduced ICG 12991 in Malawi for evaluation during a germplasm screening program for resistance to groundnut rosette disease and early leaf spot disease. ICG 12991 was released in Malawi as "Baka" in 2001. Baka can be referred to as a groundnut landrace from India that was released in sub-Saharan Africa. It is high yielding and very resistant to the groundnut rosette virus. It branches sequentially with about 4.5 and 2.5 primary and secondary branches, respectively. It has moderate oil and protein content and a shelling percentage of about 75%. It is also highly resistant to aphids. Because of its small seed size, it is hardly used by farmers for consumption but serves as one of the most experimentally interesting varieties for breeders.

Chitala (Spanish type), also known as ICGV-SM 99568 is a short-duration (100–110 days), medium seed size with good tolerance to the rosette disease (Deom et al. 2006). It is a popular groundnut variety that was released in Malawi in 2005. It is extensively used as a parental line in the development of high oleic groundnuts. It has a seed coat that is tan in colour with a 100-seed mass of 40 g and 46% oil content. It has no fresh seed dormancy.

Manipintar (or Mani Pintar) (Virginia type) is a long-duration groundnut variety with both white and red variegated seed colours, reported to have originated from the Bolivian strain of groundnuts (Smartt 1978). It was obtained from the Queensland Department of Agriculture and Stock, Australia, in the early part of 1955 (Smartt 1960). It was further developed by the Department of Research and Specialized Services in Zambia. It is one of the parents from which Nsinjiro was bred. One of its low points is its susceptibility to the rosette virus. Apart from that, it is a high-yielding variety (McEwen 1961). It is generally large (length, width, and thickness) compared to other varieties. It is late maturing (140–150 days) and fairly resistant to *Cercospora* leafspots. It produces oil with high kernel content (Smartt 1960). It remains one of the varieties that has been extensively used for academic and research purposes, and it adapts quite well to local conditions.

Empirical framework

To motivate the subsequent empirical analysis, we present a simple conceptual framework to demonstrate our understanding of the link between improved varieties and market participation. The framework presented here has been formally derived in Key et al. (2000), with some modifications by Tabe-Ojong et al. (2021a). The framework is based on the non-separable agricultural household model (Singh et al. 1986), where a household is simultaneously involved in production and consumption. As a result of market failures and imperfections in input and output markets, production and consumption decisions cannot be separated. Not only does consumption affect production but production also affects consumption and market participation resulting from surplus after consumption. More broadly, household characteristics, like demographic structure and consumption preferences, affect household decisions on production (input use and crop choice), and subsequently, market participation.

We assumed a random utility maximization framework where a household maximizes utility by choosing its production, consumption, sales quantity, and the use of inputs. Critical in this framework is the role of transaction cost, which can either induce or deter households from participating in markets depending on their size (Alene et al. 2008). Adoption of improved varieties can potentially reduce transaction costs and make market participation profitable. Transaction costs here refer to both fixed costs (search, bargaining and enforcement costs) and proportional costs (distance to markets, transportation costs) associated with the smallholder commercialization. The main pathway through which the adoption of an improved variety can reduce transaction costs is the need for less sorting and pre-screening (Tabe-Ojong et al. 2021a). Large pre-screenings and sorting are not usually needed for seeds of improved varieties, hence reducing the transaction cost per every unit sold of the improved varieties that are marketed.

In the case of groundnuts in Malawi, the improved varieties from the genebank have traits which make them easily sellable in markets after households have satisfied their food demands. Given the high quality and uniformity of the grain from improved groundnut varieties, buyers are convinced of its superiority and do not require sorting and other checks before they buy. The above two factors have serious implications on farmer's time through relaxing their time constraints. Farmers do not need to concentrate on searching for buyers or undertaking large pre-screenings before they can sell. From this, both the fixed and variable transaction cost per unit sold are expected to be lower with the improved groundnut variety from the genebank. That said, some varieties

like CG7 which is suitable for confectionery use and/or oil extraction may be another important pathway to improve market access for groundnut in Malawi. Such improved varieties from the genebank may be more easily commercialized given their current use as opposed to landraces. While landraces are likely to be locally known and trusted, their widespread marketability may not be as great because of low productivity, which may only end up satisfying household food demands. Low marketability could also be explained by high transactions costs of identification by farmers and traders outside their immediate zone of production.

Econometric model

As highlighted in the introduction, this paper examines two things: (1) the relationship between genebank ancestry and market participation and (2) the relationship between genebank ancestry and quantity of groundnuts sold. These can be more formally represented as:

- (1) The decision to sell groundnuts

$$Y_{it}^{p*} = \theta d_{it} + X'_{it}\beta + c_{i1} + u_{it} \quad (1)$$

$$Y_{it}^{p*} = \begin{cases} 1 & \text{if } Y_{it}^{p*} > 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

- (2) Quantity sold

$$Y_{it} = \delta d_{it} + Z'_{it}\alpha + c_{i2} + v_{it} \quad (3)$$

where Y_{it}^{p*} is a latent variable representing utility differences between participating and not participating in markets. X'_{it} and Z'_{it} are a vector of control variables thought to be related to market participation and quantity sold, respectively. The choice of control variables is based on the extant literature on commercialization (Carletto et al. 2017; Verkaart et al. 2017; Mango et al. 2018; Abdullah et al. 2019; Ogotu and Qaim 2019; Ochieng et al. 2020; Tabe-Ojong et al. 2021a, 2021b). Our variable of interest d_{it} represents the genebank contribution. Here, we hypothesized a positive association between genebank ancestry for both Eqs. (1) and (3), represented by the parameter estimates θ and δ .

In both Eqs. (1) and (3), there is the existence of both time-invariant unobserved heterogeneity, represented by c_{i1} and c_{i2} , and the time-variant shocks, represented by u_{it} and v_{it} . Time-invariant factors usually include characteristics that have not been measured or that are difficult to measure, such as ability, preferences, and motivation. Not controlling for this in the regression models could lead to biased estimates. Given the nature of our outcome variables, we employed both the quasi panel fixed effect

estimator and the household fixed effect estimator to control for these unobserved heterogeneities in estimating Eqs. (1) and (3), respectively.

Given that we have a two-stage model, we employed the double hurdle modelling framework (Burke 2009). In the first stage, we ran probit models, while truncated regressions were employed in the second stage. We also fit a linear probability model (LPM) as a robustness check for the probit models.

Data and variable measurements

Data

We relied on a farm household-level panel dataset collected over three time periods in the Balaka and Mchinji districts of Malawi. The survey, which began in 2008, employed a multistage sampling technique where these two districts were purposely selected based on their agro-ecological suitability and potential in groundnut cultivation. Two sections were further chosen from these districts, from which three villages were randomly selected as sampling villages. Household lists were then constructed in these villages and 12–13 farm households were randomly selected. In total, 149 households were selected and interviewed in this first survey round. These households were again interviewed in 2010 and 2013.

The survey collected information on the various groundnut varieties cultivated by households. For this, various stakeholder meetings and participatory approaches were conducted to establish the varieties farmers were cultivating. Farmers were then asked about their knowledge and adoption of these varieties.¹ Beyond varietal data conducted at the household level, we relied on pedigree data obtained from extensive consultation with scientists and breeders of ICRISAT. This was supplemented by informal discussions with some of the scientists and a review of many existing documents on the groundnut varieties. The household survey also collected information on other household- and farm-level characteristics, such as socio-economic profiles of households, area of cultivation, market participation, and transaction costs. Institutional characteristics, including extension services, were recorded.

Participatory discussions before the survey indicated that farmers are cultivating six improved groundnut varieties. These varieties, identified by their local names, are CG7, Nsinjiro, Kakoma, Manipintar, Baka, and Chitala.

¹ Previous studies (Wossen et al. 2019a; Wossen et al. 2019b) have shown that measurement errors in self-reported adoption status can be considerable. These issues were considered during the data collection exercise to make sure farmers were reporting what they cultivate. ICRISAT technicians were involved in the identification of the varieties and cross checking what farmers reported. Hence, there is high likelihood that farmers are in fact growing these varieties.

Detailed information on the groundnut varieties grown by farmers enabled us to derive clear genebank linkages after talking to genebank scientists and breeders and obtaining pedigree data.

Measuring genebank contribution

We used two different proxies to measure the contribution of the ICRISAT genebank to groundnut development. First, we used a simple binary indicator of whether any of the ancestors identified in the line of an improved variety can be traced to the ICRISAT genebank. While this proxy is straightforward and provides some insights on the genebank contribution, it has some limitations stemming from how it assigns these values. It does not differentiate between varieties for which either a single parent or both parents can be traced from the genebank. For instance, a variety will always be assigned a value of 1 whether the ancestry of a single parent or both parents can be traced to the genebank. Based on this, it does not offer actual genebank contribution. Of course, if some of the pedigree information is unknown, it may not be trivial to track the exact contribution of the genebank. In our case, we could only obtain one generation of pedigree information after detailed consultations with genebank scientists and other plant breeders. We exploited this single generation pedigree data and used the relative contribution of provenance (RCP) algorithm as our second measure of genebank contribution. Here, we apportioned genebank contribution based on the Mendelian rule of inheritance. This rule of inheritance assumes an equal contribution of every parent beyond subsequent generations (for further details, see Villanueva et al. 2020; Bernal-Galeano et al. 2020).

Results and discussion

Descriptive statistics

We present the results of the expert consultations and discussions with the genebank scientist and breeders. Based on the genebank contribution according to any ancestral parent from the genebank, we found that four of the improved groundnut varieties could be traced to the genebank (Table 2). Two of these varieties (Kakoma and Manipintar) have no identifiable relationship with the genebank. Kakoma is the product of a national breeding program in India. No information about the origins of Manipintar or links to the genebank were reported after consultations. Moving to the actual genebank contribution based on the calculated contribution from each parent, we again apportioned zeros to Kakoma and Manipintar. For CG7 and Chitala, we apportioned full provenance values of 100%, since we identified that both varieties had parents that can be traced to the genebank. A similar apportioning value

Table 2 Genebank contribution of improved varieties

Variety	Ancestry	RCP (%)	Share of total area planted
CG 7	1	100	0.70
Nsinjiro	1	50	0.19
Kakoma	0	0	0.08
Baka	1	100	0.03
Chitala	1	100	0.04
Manipintar	0	0	0.10

Table 3 Summary statistics

	Mean	Standard deviation
Outcome variables		
Market participation (yes = 1)	0.22	0.42
Quantity of groundnuts sold (kg)	51.69	181.24
Independent variables		
RCP (%)	38.26	46.04
Genetic ancestry (yes = 1)	0.44	0.49
Adoption extent (hectares)	0.38	0.74
Share of total area	0.18	0.23
Age of the household head (years)	46.33	16.04
Educational level (years)	6.90	3.62
Household head is male (%)	0.79	0.40
Household size (number)	5.40	2.14
Experience (years)	7.75	11.49
Distance to market (km)	11.54	8.12
Distance to extension agent(km)	4.79	4.22
Farm size (hectares)	1.04	1.18
Irrigation (yes = 1)	0.07	0.25
Sandy soil (yes = 1)	0.99	0.09
Ownership of radio (yes = 1)	0.49	0.50
Ownership of mobile phone (yes = 1)	0.17	0.38

To calculate the average sales level only for households who sold in markets, we obtained an average sales level of 233.39 kg with a standard deviation of 326.56.

was also given to Baka, which happens to be an Indian landrace with roots to the ICRISAT genebank. Nsinjiro was given a 50% value, since only one of its parents could be traced to the genebank.

The summary statistics of the key model variables are presented in Table 3. Market participation was low, with just about 22% of households participating in markets to sell groundnuts. Coming to the explanatory variable of interest, we reported an RCP average of 38.26%. Similarly, about 44% of improved groundnut varieties had some direct ancestral links with genebanks. Households allotted about 0.38 hectares of land for groundnut cultivation on average. Most of the household heads were males (80%) with about 8 years of experience in

Table 4 Difference between adopters and non-adopters

Variable	Pooled sample	Improved variety		Mean difference
		Adopters	Non-adopters	
Dependent variables				
Market participation (yes = 1)	0.22 (0.42)	0.43 (0.03)	0.05 (0.01)	0.39***
Quantity of groundnuts sold (kg)	51.69 (181.24)	100.77 (16.43)	12.65 (7.26)	88.11***
Key explanatory variable				
Relative provenance (%)	38.26 (46.04)	86.38 (1.77)	0.00 (0.00)	86.38***
Area under adoption (hectares)	0.38 (0.74)	0.70 (0.06)	0.13 (0.02)	0.58***
Covariates				
Age of the household head (years)	46.33 (16.04)	45.84 (1.04)	46.72 (1.08)	− 0.87
Educational level of the household head (years)	4.25 (3.96)	4.39 (0.26)	4.14 (0.26)	0.25***
Household head is male (%)	0.79 (0.40)	0.82 (0.02)	0.77 (0.02)	0.05*
Household size (number)	5.40 (2.14)	5.52 (0.14)	5.30 (0.14)	0.21
Experience in groundnut cultivation (years)	7.75 (11.49)	7.65 (0.81)	7.81 (0.73)	− 0.16
Distance to market (km)	11.54 (8.12)	11.85 (0.56)	11.29 (0.53)	0.55
Farm size (hectares)	1.04 (1.18)	1.06 (0.08)	1.02 (0.07)	0.04
Observations	447	198	249	447

For all the panel rounds, observations are pooled. Mean values are presented for all variables with their standard deviations in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1

the cultivation of groundnuts. Households had about 7 years of formal education and were generally located around extension agents.

We also performed a mean difference test to examine the differences between adopters and non-adopters (Table 4). Mean differences are observed for some of the socio-economic and contextual characteristics between these two groups of households. Adopters were generally more educated than non-adopters. Looking at our variables of interest, we observed significant differences in market participation between adopters and non-adopters. Adopters of improved groundnut varieties are more likely to participate in output markets as sellers and sell more quantities of groundnut than their non-adopting counterparts. While the results are intuitive and offer some insights into adoption, it may be inconclusive to rely on this without controlling for other confounders in a regression framework, as shown below.

Genebank contribution and market participation

The results of the empirical analyses are presented in this section, which shows the estimates of the relationship between genebank contribution and market participation. Table 5 presents a positive and significant relationship between genebank ancestry and market participation. Households that cultivated improved groundnut varieties whose ancestry could be traced to the ICRISAT genebank were more likely to participate in groundnut markets. Conditional on participating in

groundnut markets, we also obtained a positive and significant effect on the quantity of groundnuts sold.

Moving to the RCP measure of genebank contribution, the findings remained unchanged for market participation, which maintained high statistical significance (Table 6). For the conditional outcome on the quantity of groundnuts sold, the magnitudes were positive, although not statistically significant. Given the low statistical significance in the binary case and no significance in this finer algorithm of genebank contribution, the analysis

Table 5 Relationship between genebank ancestry and market participation

	Market participation (1)	Quantity sold (2)
Genebank ancestry (yes = 1)	0.197*** (0.034)	28.957* (15.557)
Additional controls	Yes	Yes
District dummies	Yes	Yes
Time dummies	Yes	Yes
R squared		0.196
Observations	447	99

Columns (1) and (2) report the relationship between genebank ancestry and market participation and the quantity of groundnuts sold, respectively. While column (1) was estimated using a pseudo fixed effect panel estimator, column (2) was estimated using a household fixed effect estimator. Other controls include the age of the household head, educational level of the household head, household size, sex of the household head, soil characteristics, irrigation access, farm size, distance to extension agent, and walking distance to the village market. Eicker–Huber–White standard errors are in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Full results are presented in the Additional file 1.

Table 6 Relationship between RCP and market participation

	Market participation (1)	Quantity sold (2)
RCP	0.017*** (0.003)	0.241 (0.155)
Other controls	Yes	Yes
District dummies	Yes	Yes
Time dummies	Yes	Yes
R squared		0.1925
Observations	447	99

Columns (1) and (2) report the relationship between the calculated theoretic genebank contribution and market participation and the quantity of groundnuts sold, respectively. While column (1) was estimated using a pseudo fixed effect panel estimator, column (2) was estimated using a household fixed effect estimator. Other controls include the age of the household head, educational level of the household head, household size, sex of the household head, soil characteristics, irrigation access, farm size, distance to extension agent, and walking distance to the village market. Eicker–Huber–White standard errors are in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Full results are presented in the Additional file 1

suggests that the cultivation of improved varieties with breeding materials from genebanks pushed smallholder households to markets, with no significant effect on quantity sold in these markets.

These results are plausible given the food insecurity status faced by many households in Malawi (Ragasa et al. 2019; Gelli et al. 2020). Based on this premise, and with insights from the non-separable household model, our findings should be correct. Faced with consumption demands, households will only participate in markets to the extent that their household food demands are met. They will only participate in markets as distress sales (to buy back later) or to sell the surplus of their production. Groundnuts constitute an essential part of the diet of most households in Malawi (Gelli et al. 2020). As highlighted by Carletto et al. (2017), the Living Standard Measurement surveys in Malawi, Tanzania, and Uganda, show that households participate in markets but sell very minimal quantities. This is even more the case in Malawi, also for food crops. Conditional on participation, an average of about 233.39 kg of groundnuts were sold by households.

The results of the (LPM) model for the two measures of genebank contribution were very similar to the original probit models, as shown in Table 7. This confirms the robustness of our estimates and further bolsters the positive association between genebank contribution and market participation of smallholder farmers in groundnut markets.

Mechanism

Once we established a positive association between genebank contribution and market participation, we sought to examine the mechanism through which improved

Table 7 Robustness check using LPM specification

	Market participation	
	(1)	(2)
RCP	0.021*** (0.003)	
Genetic ancestry (yes = 1)		0.227*** (0.035)
Additional controls	Yes	Yes
District dummies	Yes	Yes
Time dummies	Yes	Yes
R squared	0.442	0.434
Observations	447	447

Columns (1) and (2) report the relationship between the theoretic genebank contribution and genebank ancestry and market participation, respectively. Both models were estimated using a pseudo fixed effect panel estimator. Other controls include the age of the household head, educational level of the household head, household size, sex of the household head, soil characteristics, irrigation access, farm size, distance to extension agent, and walking distance to the village market. Eicker–Huber–White standard errors are in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Full results are presented in the Additional file 1

varieties produced with materials from ICRISAT genebank leads to market participation. Previous literature (Bezu et al. 2014; Carletto et al. 2017; Verkaart et al. 2017) have highlighted the role of the extent of adoption in driving various welfare outcomes. We therefore verified if this explains the market-orientation of households. We refer to the extent of adoption as the area under improved groundnut. We performed two different sets of regressions to establish whether the extent of adoption is the underlying mechanism explaining the relationship between genebank ancestry and the market outcomes. First, we regressed the area under improved groundnut on our market outcomes. We hypothesized a positive association between adoption extent and market participation. Second, we took a step to further confirm whether our genebank proxies have any relationship with the extent of adoption.

For the first regression, we employed both panel and pseudo-panel, fixed estimators to control for time-invariant unobserved heterogeneity, given that our outcomes have different within-variation properties. We also controlled for time-variant unobserved characteristics using a control function approach with the specification of three instruments. We estimated a Tobit model of adoption extent, including soil characteristics, access to irrigation, and distance to extension agents, which served as a source of exogenous variation. From this, we calculated the generalized residual, which we used in the main outcome equations. Including this residual in the outcome equation served as both a test of endogeneity and a way of controlling it (Wooldridge 2015).

The results of Table 8 show the relationship between adoption extent and market participation. As hypothesized, adoption extent increases the participation of

Table 8 Relationship between adoption extent and market participation

	Market participation (1)	Quantity sold (2)
Adoption (hectares)	0.075*** (0.021)	44.912***
Additional controls	Yes	Yes
District dummies	Yes	Yes
Time dummies	Yes	Yes
R squared		0.269
Observations	447	99

Columns (1) and (2) report the relationship between the extent of groundnut adoption and market participation and the quantity of groundnuts sold, respectively. While column (1) was estimated using pseudo-panel, fixed effect estimators, column (2) was estimated using a household fixed effect estimator. Other controls include the age of the household head, educational level of the household head, household size, sex of the household head, soil characteristics, irrigation access, land ownership, farm size, distance to extension agent, and walking distance to the village market. Eicker–Huber–White standard errors are in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Full results are presented in the Additional file 1

Table 9 Genebank contribution and adoption extent

	Adoption extent	
	(1)	(2)
RCP	0.013*** (0.001)	
Genetic ancestry (yes = 1)		1.424*** (0.146)
Additional controls	Yes	Yes
District dummies	Yes	Yes
Time dummies	Yes	Yes
R squared	0.233	0.269
Observations	447	447

Columns (1) and (2) report the relationship between the theoretic genebank contribution and genebank ancestry and the extent of adoption, respectively. Both models were estimated using pseudo fixed effects panel estimators. Other controls include the age of the household head, educational level of the household head, household size, sex of the household head, soil characteristics, irrigation access, farm size, distance to extension agent, and walking distance to the village market. Eicker–Huber–White standard errors are in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Full results are presented in the Additional file 1

smallholder farmers in groundnut markets. In both outcomes, the results are highly statistically significant, suggesting that the extent of adoption may well be the mechanism explaining the positive association of genebank contribution on market participation.² Looking at the relationship between our two measures of genebank contribution and the extent of adoption, we further reported a positive association, which was again highly significant at the 1% level of probability (Table 9). Our results here are in line with earlier findings that

commercialization increases with the area of cultivation (Carletto et al. 2017).

Conclusion

In this study, we have provided novel evidence of the role of the ICRISAT genebank in the development of improved groundnut varieties and further associated this with market participation of smallholder farmers. Using pedigree data combined with a three-wave household-level panel dataset, we began by apportioning the contribution of the ICRISAT genebank to the development of six improved groundnut varieties used in Malawi. We found that four of the six varieties could be traced to the ICRISAT genebank using simple indicator measures, which we further confirmed using more suited algorithms, like the RCP. After apportioning these values, we estimated a double hurdle model to estimate how these related to the market participation and sales intensity decisions of households. We found the genebank linked smallholders to groundnut markets with little discernible effect on the sales quantity. In line with previous studies, we also found the area under improved groundnuts to be the underlying mechanism driving the farmers to markets.

We provide a relevant entry and leveraging point for not only boosting the adoption of improved varieties but also for encouraging market participation of farmers through genebanks. Genebanks matter directly for varietal development, and indirectly for market participation of smallholders. First, access to genetic resources from genebank could lead to the development of improved varieties with better yields and traits that are highly suited and resistant to emerging shocks and diseases. Increased productivity encourages market participation through the availability of production surplus. Second, access to genetic resources from genebanks could lead to the development of improved varieties that provide incentives for market participation. These incentives relate to the development of varieties with better grain quality traits leading to reduced market costs, due to the less need for pre-screening and grain sorting, and to increased market sales due to consumer preferences. In both settings, enhanced access to crop diversity from genebanks, as sources of useful traits for varietal improvement, is key.

Our results demonstrate the importance of the genebank in the development of new varieties adopted by smallholders with a direct impact in their market participation and highlights the importance of the continuous global movement of germplasm. Currently, the

² In other words, varieties with genebank ancestry are just more attractive to farmers, which makes them grow more area in them, leading perhaps to having enough of the right grain quality to sell.

ITPGRFA guarantees the easy access to germplasm for food and agriculture, however, the MLS is restricted to 64 crops listed in its Additional file 1. With groundnut not being included in this list, the movement of this crop's germplasm has declined. Although the ICRISAT genebank continues to share the materials conserved in its cold rooms following Article 15 of the Plant Treaty, the acquisition of new diversity by this and other genebanks has been extremely rare. Also rare is the availability of groundnut germplasm from other genebanks. Moreover, it is correct to say that significant diversity still not collected and conserved in ex situ collections is being lost due to the impact of climate change in the natural areas. Thus, new sources of diversity are not accessible to the breeding programs that support smallholders. International policy to guarantee the easy access and benefit sharing are in place, as already discussed, but need to be improved substantially to guarantee that relevant crops such as groundnut are represented and easy access is guaranteed.

We end by mentioning some limitations of our study which could be taken up in future research. Despite establishing a link between genebank ancestry and market participation of smallholder farmers and controlling for unobserved heterogeneity through panel data methods, no identification strategy is perfect. Additional research may be worthwhile to streamline to confirm this link. Moreover, as with any empirical analysis, context matters. However, we consider that the situation in Malawi may not be different from other farming systems in developing nations where market participation is often hampered by production side constraints such adoption of improved seeds and farm inputs as well as institutional factors. Finally, even though the unique dataset on improved groundnut varieties presents a valuable contribution to the study of specialty crop adoption in developing countries, the pedigree depth contains only one generation, which for the six varieties included in the study does not add much variation. Longer pedigree information could provide more insights on the links between genebank ancestry and smallholder welfare through enhanced market participation, as would detailed data on trait performance in field trials or hedonic analysis of trait values in local markets.

Abbreviations

ESA: Eastern and Southern Africa; CGIAR: Consultative Group of International Agricultural Research; ICRISAT: International Crops Research Institute for the Semi-Arid Tropics; ITPGRFA: International Treaty on Plant Genetic Resources for Food and Agriculture; RCP: Relative contribution of provenance; LMP: Linear probability model.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s43170-022-00082-x>.

Additional file 1: Table S1. Relationship between RCP and market participation (full results). **Table S2.** Relationship between genetic ancestry and market participation (full results). **Table S3.** LPM specification (full results). **Table S4.** Relationship between adoption extent and commercialization (full results). **Table S5.** Genebank contribution and adoption extent (full results).

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Authors' contributions

MPJr.TO contributed to the research conceptualization and design, data gathering and cleaning, data analysis, writing, and editing. NS and NJ contributed to the research conceptualization and design, writing, editing, supervision and funding acquisition. VA contributed to pedigree data provision, writing, and editing.

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Availability of data and materials

The data used for this analysis is readily available and can be accessed at <http://dataverse.icrisat.org>. More information about the analyses and the result files are available from the author upon request.

Declarations

Ethics approval and consent to participate

The study involved no ethics approval.

Consent for publication

All authors have consented to the publication of the manuscript.

Competing interests

The author declares no competing interests.

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