AgriGender *Journal of Gender, Agriculture and Food Security*

AgriGender 2019; **Volume 04, Issue 01**, 38–50, doi:10.19268/JGAFS.412019.4

Reducing gender gaps in the awareness and uptake of drought-tolerant maize in Uganda: The role of education, extension services and social networks

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Cultivation of drought-tolerant (DT) maize seed reduces drought risk in sub-Saharan Africa. Data from eastern Uganda reveal gender gaps in awareness and adoption of DT maize. Among surveyed male household heads, 67.6 percent had awareness of DT maize varieties and 29.2 percent grew them. Corresponding figures for female household heads were 43.3 percent (awareness) and 5.3 percent (adoption) and those for wives in spousal couple households were 51.0 percent and 11.1 percent. Propensity score matching (PSM) found that awareness of the technology has a decisive role in DT maize adoption. Regression analysis indicated that education exerts the greatest influence on agricultural technology awareness for female household heads, while social networks matter most for wives of male household heads. Policies leading to gender equity in access to education and agricultural information resources would give women farmers similar awareness of DT maize seed as men farmers and reduce the gender technology gap.

Keywords: Adaptation, Africa, Agricultural Technology, Climate Change, Gender, Uganda.

Introduction

In sub-Saharan Africa (SSA), "maize is life": essential to the food security and economic well-being of more than 32 million households (Fisher et al 2015). Increasing maize productivity in this region is thus of critical importance to improving food security and rural livelihoods. Even though some countries in SSA have made good progress in the productivity of maize (Abate et al 2015), the overall average is still far behind what could be achieved with improved cultivars and good management. Smallholder farm households in SSA grow up to eight maize cultivars (average = 1.78) per season and the average variety age is 15 years (Abate et al 2017). This slow variety turnover is the main explanation for the overall low productivity of maize in the region. The Global Yield Gap Atlas (http://www.yieldgap.org/) provides the following estimates for Uganda for actual yield, potential yield, and yield gap of rainfed maize: 1.6, 6.8, and 5.2 tons per harvested hectare at standard moisture content. Maize productivity gains in SSA can be fostered by replacing the old cultivars with more recent releases that are tolerant or resistant to multiple stresses and more resilient in the face of climate change and variability. Drought is among the major causes of low agricultural yields and high season-to-season yield variability in SSA (Shiferaw et al 2014). It is estimated that the annual yield loss in maize due to drought is between 15 and 90 percent, depending on the maize cropping stage at which drought occurs (Bänziger and Araus 2007).

This study focuses on recent advances in maize research that could help African farmers adapt to drought, ultimately reducing vulnerability and improving food security. Between 2007 and 2015, the Drought Tolerant Maize for Africa (DTMA) project released more than 230 new maize varieties with multiple stress tolerance — including drought, major diseases such as the maize streak virus and turcicum leaf blight, and attack by the parasitic witch weed (*Striga hermonthica*). These varieties produce the same or higher yields than the currently available commercial maize varieties (Setimela et al 2017). Many of these new maize varieties, DT maize varieties, as they are usually referred to, possess additional desirable traits including improved nitrogen use efficiency and nutrition quality (also known as quality protein maize, or QPM).

Cultivation of DT maize is an agricultural adaptation that is relatively low-cost and easy for farmers to use. It also reduces the need for harmful strategies for dealing with crop failure, such as borrowing, reducing food consumption, selling household assets, or taking children out of school. Farmers in SSA express considerable demand for crop varieties that are less sensitive to climatic stress, such as DT maize (Westengen and Brysting 2014), but it is only since implementation of the DTMA project that this option to drought adaptation has become widely available.

One of the challenges to widespread adoption of DT maize is ensuring these seeds meet the needs of a diverse set of farmers, including both men and women. While modern seed varieties are intended to benefit a wide range of producers, empirical studies reveal that women farmers have relatively low rates of adoption of agricultural technologies associated with increased crop yields (Peterman et al 2014). Research also suggests that men are more likely than women to adopt measures for adapting to climate change, such as soil conservation, tree planting and changing crop varieties (Deressa et al 2009; Van Aelst and Holvoet 2016).

This paper uses the case of the DTMA project in eastern Uganda to understand the gender gap in adoption of modern seed varieties. National household survey data reveal that drought is a persistent problem: 49 percent of respondents reported that drought or dry spells lasted more than five months in each of the five years prior to the survey (Hisali et al 2011). Despite the perceived risk of drought and the potential benefits of DT maize seed, uptake of DT maize remains low and is marked by a significant gender gap. Data from eastern Uganda used in the current study reveal that in the 2014 major season, 29.2 percent of surveyed male household heads (MHHs) grew DT maize varieties. Corresponding figures for female household heads (FHHs) and wives in spousal couple households were 5.3 percent and 11.1 percent, respectively.

One main explanation for the gender gap in agricultural technology adoption is that women farmers are less aware of new technologies than men. For example, a study of adoption of tissue culture banana technology in Kenya, showed that female farmers are less likely to adopt the technology, but would be as likely as male farmers if they had sufficient information about the innovation (Kabunga et al 2012). Another study in Kenya predicted that uptake of sustainable agricultural practices would significantly increase if women and men farmers had similar access to agricultural extension services (Ndiritu et al 2014). Our survey data for eastern Uganda indicate a significant gender gap in awareness of DT maize (defined herein as having heard of one or more DT maize varieties): 43.3 percent of female household heads (FHHs), 51.0 percent of wives in spousal couple households, and 67.6 percent of male household heads (MHHs) were familiar with the technology.

Gender-disaggregated data from eastern Uganda is used to examine the determinants of gender-based differences in DT maize awareness and to measure the impact of awareness on technology uptake. Our aims are to understand why women farmers have lower technology awareness and reveal the degree to which technology awareness impacts uptake. The focus on technology awareness is critical given DT maize is a relatively new, unfamiliar technology. A recent six-country study found that lack of information was a main reason that farmers in Uganda, Zambia, and Zimbabwe had not yet tried growing a DT maize variety (Fisher et al, 2015). Fisher and Carr (2015) using the eastern Uganda dataset employed herein attributed the gender gap in DT maize adoption to gender-based differences in resource access, notably land, credit, and agricultural information.

The next section of the paper reviews literature that stimulated the study hypotheses that lower awareness of DT maize among women vs. men farmers is due to gender-based differences in educational attainment, access to extension services and social network composition. We then describe the data and study context. This is followed by two sections that present the empirical models and results. In the final section, the implications of the study findings for the development of well-targeted and socially-inclusive adaptation policies are discussed.

Gender-Based Differences in Access to Educational Opportunity and Extension Services and in Social Network Structures in Sub-Saharan Africa

Technology awareness is the first stage of the two-stage adoption process in which farmers gain awareness by acquiring information from an adequate number of sources (Lindner et al 1982). In the second stage, the farmer uptakes the new technology, if she/he is sufficiently convinced that the expected benefits exceed the expected costs and has the necessary land, labor, and cash for adoption. Farmers gain awareness of new technologies from agricultural extension efforts, by observing and interacting with other adopters, and through experimenting with the technology (Baerenklau 2005). In many contexts, the prevailing gender norms may hinder the ability of women to gain awareness of new technologies by constraining their access to extension services, interactions with other farmers, and educational opportunities. Below we review literature on gender-based differences in access to extension services and educational opportunities and in social network structures.

Gender-based differences in access to agricultural extension services

Studies on agricultural extension services highlight several challenges in reaching rural women in SSA and other developing regions. First, the perception bias that "women are not farmers" persists among extension services (Ragasa 2014), despite the fact that women make essential contributions to agriculture in developing countries and make up an average of 50 percent of the agricultural labor force in SSA (FAO 2011). Because the farmer is typically believed to be male, extension agents target men for extension activities and do not recognize the need to make extension services more accessible for women, for example, by having meetings at times when women are free from their childcare and other domestic responsibilities.

Second, extension agents often assume that information provided to one household member (e.g. the husband) will trickle across to other household members (e.g. the wife). Country studies in SSA do not support this assumption. In a Malian survey, only 18 percent of women cited their husband as an important source of production information, and in Burkina Faso, only 1 percent of women said they receive production information from their husbands (for a review of studies, see Fisher et al 2000).

Third, since extension services have traditionally been designed for farmers with access to or ownership over land (Meinzen-Dick et al 2011), gender inequalities in land ownership reduce women's access to extension services. In SSA, women make up only 15 percent of agricultural landholders, on average, with considerable variation across countries. Thus, extension services often unintentionally bypass women (Ragasa 2014).

The fact that most extension agents in SSA are male also affects women's ability to access information. A recent study by the World Bank and IFPRI found that 10 of the 70 agricultural extension agents surveyed in Ghana were female, and in Ethiopia, agents were overwhelmingly male (Ragasa 2014). The male dominance of agricultural extension services is problematic in societies where cultural and societal norms prohibit, discourage, or make it awkward for women to interact with men aside from close relatives (Fletschner and Mesbah 2011). Women may be reluctant to participate in training sessions that are led by men or ask questions of male extension agents (Primo 2003 cited in Fletschner and Mesbah 2011). In Tanzania, a survey of female farmers visited by an extension agent revealed that 40 percent preferred a female agent, 26 percent a male agent, while 34 percent were neutral (Due et al 1997). The main explanation provided was that women felt more comfortable discussing their problems with other women.

With the increasing importance of information and communication technologies (ICTs) for delivering agricultural messages, it is important to consider whether men and women have similar access. A study in 17 countries of SSA (Gillwald et al 2010) shows that rural women are disadvantaged compared to rural men with respect to ICT access. In Uganda, for example, rates of ownership of a mobile phone or SIM card were 13 percent (women) and 29 percent (men), while radio ownership rates were 55 percent (women) and 79 percent (men), reflecting women's lower average income and education. Encouraging, however, are results from a recent survey by the Uganda Communications Commission (2015) which shows increased ownership of radios and mobile phones and a narrowing of the gender gap. Radio ownership was 82 percent for females and 84.9 percent for males, while mobile phone ownership was 44.4 percent for females and 61.6 percent for males.

Gender-based differences in social network structures

Since farmers often mention other farmers as their most important information source (Rogers 2010), women and men may have differential access to information if social networks differ on gender lines. Several attributes of social networks are expected to determine their degree of utility for influencing awareness and uptake of DT maize and may vary based on gender: network diversity, the mix of kin and non-kin, and the share of network ties that cultivated DT maize.

Having diverse networks is considered an advantage for accessing resources and information enabling people to reach other social realms and obtain non-redundant information (Granovetter 1973; Rogers 2010). Farmers with communication networks that span different villages and socio-demographic profiles are expected to have a greater likelihood of gaining awareness of new technologies such as DT maize than farmers who communicate about farming only with proximate individuals. Rural women in SSA might be expected to have fewer network links with farmers from outside their village, either owing to time constraints or restrictions on their mobility. Research has shown that social networks are often segregated based on gender, as described for example by Aryeetey (1995) for seed technology diffusion in Ghana and Magnan et al (2015) for laser land leveling diffusion in India. Where social networks are highly gender segregated, existing gaps in men's and women's access to information are likely to be reinforced (Fletschner and Mesbah 2011).

While kin may be valuable sources of social support, they are not as useful for economic advancement as non-kin (Renzulli et al 2000). Research from the US suggests that, compared to men, women have more ties to kin and fewer connections to non-kin individuals, with a partial explanation being women's greater allocation of time to home and childcare activities (Moore 1990).

Having social network members who grow DT maize clearly offers an advantage in terms of learning about this emerging technology. Research from India found that men were more likely than women to be connected to wealthier and more progressive farmers (Magnan et al 2015), farmers who would be expected to be early adopters of new technologies.

Gender-based differences in educational opportunities

Low levels of education can hamper the ability to decipher and interpret information on new technologies and participate in extension activities requiring reading and arithmetic skills (Foster and Rosenzweig 2010; Ragasa 2014). While considerable progress towards gender parity in primary and secondary education has been made in recent years, there are only 92 girls per 100 boys in primary school in SSA, and gender disparities widen the higher up the education system you go (UNESCO 2015). This pattern reflects girls' domestic responsibilities and the social practices that give priority to the education of boys over girls. The gender differential in adult literacy is particularly stark: two-thirds of adults who lack basic skills are women, a proportion unchanged since 2000. Half of the adult women in SSA cannot read or write.

It is with this literature in mind that we seek to understand differences in awareness of DT maize seed by women and men farmers in Uganda, where differences reflect distinct gender norms that shape the patterns of information access. This literature guides the development of an empirical model to test three hypotheses for how gender influences awareness of DT maize seed. Before turning to the empirical modeling, however, the next section describes the Uganda household survey data and the study context.

Study Context and Data

Survey sampling and data collection

Data for this study are from a 2014 household survey of 408 households and 691 individuals (householders and their spouses) in the eastern region of Uganda. At each sampled household, we asked members to identify the household head and his/her spouse. In all cases of spousal couple households, the husband was identified as the household head. The 691 sampled individuals included 60 female household heads (FHHs), 333 male household heads (MHHs), and 298 wives in male-headed households. Almost all FHHs in the sample were widowed, divorced, or never married; only one of the FHHs was married with an absent spouse. One limitation of our study is our focus on heads and spouses. Interviews with primary males (e.g., a brother or adult son) in those households headed by a female would provide additional information on intrahousehold dynamics.

The eastern Uganda households are a sub-sample of a total of 720 households surveyed in eastern, western, and central Uganda, where DT maize varieties have been promoted. More than half of the total surveyed households come from the Eastern Region, due to its higher population size and maize production relative to the other regions. The present study uses only the Eastern Region data because it includes gender-disaggregated data not collected in the other regions.

The survey was a collaborative effort between the International Maize and Wheat Improvement Center (CIMMYT), lead institution, Michigan State University, Makerere University, and Uganda's National Agricultural Research Organization (NARO). Sampling began with a list of DTMA-dissemination districts in the three Uganda regions from which we chose districts and villages with population proportionate to size sampling, using information from the 2012 Uganda Census. In the Eastern Region, three districts and 34 villages were selected in this way. From each sampled village, a simple random sample of 12 households was selected for the interview. Given the sampling design, results of the study should be generalizable to the eastern region of Uganda.

In each study village, the survey began with implementation of a village questionnaire with four key informants to collect village-level information on demographics, economic activities, institutions and infrastructure, maize growing conditions, and wages/prices. The survey next turned to face-to-face interviews with household members using two structured questionnaires (a household and an individual questionnaire). Household heads were the main respondents of the household questionnaire. In spousal couple households, efforts were made to include spouses in the interviews. The household questionnaire collected information on demographics, agricultural landholdings, maize varieties cultivated, agricultural input use, the quantity of maize harvested and sold, and socio-economic conditions. Information collected on agricultural inputs and outputs covered both the 2014 major and 2013 minor seasons.

For the individual questionnaire, which was implemented only in eastern Uganda, the household head and, where applicable, the spouse was interviewed. A total of 691 individuals were interviewed. The interviews with householders and their spouses took place concurrently but privately, and we usually matched the gender of the interviewer to that of the respondent. The questionnaire collected gender-disaggregated data on drought-risk perceptions, technology preferences, awareness of DT maize seed, credit access, access to agricultural information by source (e.g. extension service, research, media), social capital, and social networks.

The social network module began by asking the respondent to name up to five farmers who she/he regularly talks to about maize farming. Subsequent questions solicited attributes of the network members, such as age, education level, farm size, location, and adoption of DT maize. Information was also collected to characterize the nature of the social links, such as how often meetings take place, the usual way information on maize farming is exchanged, and the relationship between the respondent and social network members.

The study area

The eastern region of Uganda, where the study was conducted, is bordered by Kenya, includes part of Lake Victoria, and covers an area of 39,479 hectares (16 percent of Uganda's total area). The region's population is estimated at 9,154,960 of which about 90 percent live in rural areas. Elevation ranges between 1,075 and 1,524 meters above sea level. The mean annual rainfall varies from 1,374 to 2,058 mm, with significant annual and seasonal variation in the amount and distribution pattern (Kansiime et al 2013).

Agriculture is the main source of livelihood in eastern Uganda and the country as a whole. Maize occupies the largest area of all crops, accounting for 16.7 percent of cropped area in Uganda according to FAOSTAT 2019 data and is grown by the largest number of households. It is produced both for home consumption and sale, with the latter being more important. In a recent household survey in Uganda's Central and Eastern Regions, respondents reported the following uses of their maize harvest: home consumed (15.9 percent), sold (75.9 percent), given out (4.1 percent), reserved as seed (2.1 percent), and lost (1.8 percent) (Mugisha et al 2011). Regionally, the highest maize production is in the Eastern Region (47 percent), and the lowest in the Northern Region (13 percent) (UBOS 2010). Other important crops in the Eastern Region are cassava, common bean, sweet potato, bananas, coffee, sesame, and tea.

Uganda has seven agro-climatic zones demarcated based on spatial differences in soils, topography, and climate (Hisali et al 2011). The country has two distinct growing seasons: the main growing season from March to June, and the second, lighter rains from September to December. In years of reliable rainfall, the possibility of growing crops in two seasons enables farm households to grow adequate food to feed their families and the country to be self-sufficient in staple food production (FEWS NET 2017). Uganda is a regular exporter of staple foods to neighboring structurally deficit countries (Kenya, South Sudan, and the Democratic Republic of Congo).

Over the past decade, drought has occurred frequently over eastern Africa, including Uganda, but both the frequency of drought episodes and the duration of conditions with below-average rainfall have been greater in recent years. Recent drought events, with widespread conditions of well-below-average rainfall, occurred during 1998, 2000, 2005/06, 2007, 2008, 2009, and 2011 (Nicholson 2014). Nationally representative household survey data for Uganda reveal that drought is a persistent problem, with 49 percent of respondents reporting that drought or dry spells lasted more than five months in each of the five years prior to the survey (Hisali et al 2011). The same survey documents a range of adaptation practices households employ in response to various climate events. For the case of drought, the most commonly mentioned adaptations were drawing down on savings (38 percent), reduced consumption (29 percent), and increased labor supply (23 percent). Technology-based adaptations represented only 5 percent of drought-related adaptations at the time of the survey (2005/06).

In Uganda, the National Agricultural Advisory Services (NAADS) was the main source of advisory services until now, and therefore during the time period the current study concerns; private extension agencies offered only specialized services (AfranaaKwapong and Nkonya 2015). The NAADS operated a demand-driven extension approach, working through farmer groups at village level. These farmer groups regularly recommended priority enterprises and advisory service needs, and a farmer forum then selected three priority enterprises per sub-county. NAADS provided farmer support by supplying technologies for demonstration (the responsibility of host farmers in farmer groups) and offering advisory services. Recent estimates of the number of NAADS agricultural extension agents per 100,000 rural people for the three districts that are part of the current study varied from about 5–8 (Iganga District) to more than 14 (Tororo District) (AfranaaKwapong and Nkonya 2015). Countrywide, the extension agent to farmer ratio was estimated in 2014 at 1 to 5,000 compared to a recommended 1 to 500 (MAAIF 2016a, 2016b). Following farmer dissatisfaction with the NAADs model of extension, a new single spine agricultural extension model has been put in place and a directorate created within the Agriculture Ministry to manage agricultural extension. The NAADS secretariat has been restructured and tasked to handle strategic interventions and promotion of value addition technologies only (MAAIF 2016a, 2016b).

A diverse set of local formal and informal social institutions are in operation in Uganda. A study in eight Uganda districts (Hassan and Birungi 2011) found 22 functioning social groups and categorized them as production and financial services groups (e.g., savings and credit associations, farmers' groups), supra–community organizations (e.g., government programs, NGOs), and social service groups (e.g., burial societies, religious groups). The same study indicated that locally initiated institutions are most common, accounting for 84.1 percent of total group membership, and found most groups to be ethnically homogenous.

The most recent estimates from UNESCO (http://uis.unesco.org/country/UG) document a gender gap in literacy, but near gender parity in indicators of education progress in Uganda. The literacy rate for individuals 15 years and older is 79 percent (males) and 62 percent (females). Survival to the last grade of primary is 35 percent for males and 36 percent for females, while the primary to secondary transition rate is 61 percent (males) and 57 percent (females). Data from our eastern Uganda study sites indicate low educational attainment and existence of a gender educational gap in the three study districts, with the average number of years of school completed being only 6.7, 5.1, and 3 years for MHHs, wives in spousal couple households, and FHHs, respectively (Table 1).

The DTMA project and its implementation in Uganda

The DTMA project made releases of more than 230 DT maize varieties between 2007 and 2015. In Uganda, NARO has released 15 DTMA varieties (DTMA 2015). In addition to drought tolerance, some of the Uganda varieties are nitrogen use efficient. But none of the Uganda DT varieties are QPM. Importantly, compared with other commercial maize varieties, the new DT maize varieties produce the same or higher yields (as described in the next paragraph) and have similar or lower input costs. Seed companies in Uganda have priced the DT maize seed to be no higher than prices of other (i.e., non-DT) modern maize seed. Requirements for inputs such as labor and pesticides are similar for DT maize and other modern maize varieties. And fertilizer costs could be lower for DT maize, because some of the varieties released in Uganda are nitrogen use efficient, meaning they utilize more efficiently (compared to other modern maize varieties) the small amount of commercial fertilizer farmers can afford to apply.

The new DT maize varieties underwent extensive multi-location on-station and on-farm testing using a participatory variety selection approach with farmers. In the 2008/09 and 2009/10 production seasons (both major and minor seasons), on-station trials in four types of environments across 44 locations in eastern and southern Africa (ESA), including Uganda, found that the top-yielding DT maize variety out-yielded the most preferred farmer commercial check by 168 percent (under drought), 82 percent (random stress, i.e. occurrence of pests, disease, and dry spells of varied intensity), and 22 percent (optimal rainfall conditions) (Setimela et al 2017). The same study found more modest, yet still substantial yield gains on farmers' fields across 80 locations in ESA, including sites in Uganda. In the 2010/11 and 2011/12 seasons, 20 promising DT maize hybrids and OPVs had a yield advantage over commercial check varieties in the range of 4 to 19 percent, across a diverse set of farmer conditions, with the largest gains achieved under stress conditions (Setimela et al 2017). Uganda was among the locations of both the on-station and on-farm trials (personal communication, Peter Setimela, April 2018).

Across the 13 DTMA countries (Angola, Benin, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Tanzania, Uganda, Zambia, and Zimbabwe) seed delivery has been the responsibility of national agricultural research systems and public and private seed companies. In Uganda, the new DT maize varieties have been promoted mainly by private seed companies who obtain foundation maize seed from the National Crops Resources Research Institute, multiply the seed, package it in packets appropriate for smallholder farmers (2kg, 5kg, and 15kg), and market it to various agro-dealers or directly to smallholder farmers. Many of these seed companies conduct participatory breeding/variety selection with farmers, set up demonstration plots in villages, and work with extension agents to link farmers to input markets. Seed companies have a key role to play in ensuring that women farmers gain awareness of and have access to the new DT maize seed. While several seed companies in Uganda reportedly make some effort to include women farmers in training, extension, and demonstration activities, only one seed company, Victoria Seeds, explicitly targets women farmers (Access to Seeds Foundation 2016). One other company, Nalweyo Seed Company (NASECO), is said to include women farmers in participatory variety selection, although the degree to which women's preferences are incorporated into the company's maize breeding decisions is not known.

Variable	FHHs (*n* = 60)			Wives (*n* = 298)			MHHs (*n* = 333)		
	Mean or proportion	90% Conf. interval		Mean or proportion	90% Conf. interval		Mean or proportion	90% Conf. interval	
Awareness of DT maize	0.433	0.326	0.541	0.510	0.462	0.558	0.676	0.633	0.718
Age (years)	55.683	53.087	58.279	35.718	34.568	36.868	43.187	41.843	44.530
Main occupation is farmer	0.917	0.857	0.977	0.956	0.937	0.976	0.784	0.747	0.821
Education (years)	3.017	2.260	3.773	5.091	4.778	5.404	6.699	6.388	7.010
Household size	5.783	5.240	6.327	7.446	7.140	7.752	7.205	6.897	7.513
Farm size (acres)	2.473	2.152	2.794	3.404	3.181	3.626	3.357	3.148	3.566
Drought perception 1	1.783	1.473	2.094	1.492	1.376	1.607	1.390	1.286	1.494
Main information source 2									
Extension visits	0.033	-0.006	0.072	0.030	0.014	0.047	0.039	0.022	0.057
Research	0.000	0.000	0.000	0.020	0.007	0.034	0.045	0.026	0.064
Input shops	0.000	0.000	0.000	0.013	0.002	0.024	0.045	0.026	0.064
Other farmers	0.167	0.086	0.248	0.174	0.138	0.211	0.156	0.123	0.189
Electronic media	0.100	0.035	0.165	0.174	0.138	0.211	0.207	0.171	0.244
Social network members (SNMs)									
Number	2.467	2.117	2.816	2.507	2.356	2.657	3.162	3.016	3.308
Number of kin	1.250	0.946	1.554	1.003	0.877	1.129	1.351	1.218	1.484
Number of non-kin	1.017	0.721	1.313	1.235	1.102	1.367	1.492	1.365	1.620
Same sex only	0.217	0.127	0.306	0.339	0.294	0.384	0.760	0.721	0.798
Opposite sex only	0.350	0.246	0.454	0.285	0.242	0.328	0.024	0.010	0.038
Both sexes	0.333	0.231	0.436	0.265	0.223	0.307	0.147	0.115	0.179
From outside village	0.233	0.141	0.325	0.208	0.169	0.247	0.297	0.256	0.339
Grew DT maize	0.250	0.156	0.344	0.242	0.201	0.283	0.378	0.334	0.422
Village variables									
Distance from village to tarmac (km)	9.763	7.309	12.217	9.236	8.291	10.181	9.394	8.473	10.315
Number DT varieties grown in village	1.300	1.075	1.525	1.453	1.320	1.586	1.441	1.315	1.568
Too little rain in village	0.117	0.048	0.226	0.171	0.130	0.219	0.159	0.122	0.203

Bugweri county	0.117	0.047	0.187	0.154	0.120	0.189	0.159	0.126	0.192
Kigulu county	0.217	0.127	0.306	0.215	0.175	0.254	0.207	0.171	0.244
Tororo county	0.083	0.023	0.143	0.158	0.123	0.193	0.150	0.118	0.182
West Budama county	0.300	0.200	0.400	0.279	0.236	0.321	0.261	0.221	0.301
Bulambuli county	0.283	0.185	0.381	0.195	0.157	0.233	0.222	0.185	0.260

Notes:

1. Defined as the reported number of years in the last five in which the household experienced drought-induced maize harvest loss.
2. The proportions for the main information source do not sum to 1, because less than half of the respondents reported receiving information on new maize seed last year.

Table 1 Descriptive statistics of model variables for female household heads (FHHs), wives in spousal couple households, and male household heads (MHHs).

Empirical Approach

Estimating the determinants of DT maize awareness

We examine whether the lower awareness of DT maize among women vs. men farmers reflects that women are less educated and have less access to technical advice and information on new seed. A series of logit regression models are estimated which are variants of

$$A = \alpha_0 + \alpha_1 F + \alpha_2 W + \alpha_3 E + \alpha_4 I + \alpha_5 S + \alpha_6 X + \varepsilon \qquad (1)$$

In equation (1), the dependent variable A is a binary variable for DT maize awareness. Explanatory variables are indicators for female householders (F) and wives (W), a continuous measure of the individual's educational attainment (E), a set of binary variables for the main source of information on new maize seed (I), several variables related to the individual's social networks (S), and a set of control variables (X, including the individual's age and drought risk perception, a binary variable for farming as main occupation, the number of household members, landholding size, distance from the village to the nearest tarmac road, the number of DT maize varieties grown in the village, village key informants' assessment of whether recent rainfall in their area was sufficient for maize cultivation, and county fixed effects). Finally, in equation (1), ε is a random error term assumed uncorrelated with the regressors.

The base regression model includes only the controls and the female binary variables. The second regression model adds educational attainment. The third and fourth regressions include, along with the female binary variables and controls, either the information source or social network variables. The final regression model includes the full set of regressors. We anticipate that the relationship between gender and technology awareness will be reduced considerably or become insignificant when we control for education, access to extension information, and social learning. Below we briefly outline our hypotheses related to these variables.

We hypothesize that lower awareness of DT maize by women vs. men farmers is explained by gender-based differences in educational attainment (Hypothesis 1), access to extension services (Hypothesis 2), and the characteristics of social networks (Hypothesis 3). Three steps make up the testing of the study hypotheses. One source of empirical support is a finding that controlling for the variables of interest (i.e. education, extension, social networks) causes the estimated coefficients on the female binary variables to become smaller in absolute value or non-significant. Second, results of the logit model indicate whether the variables of interest significantly influence awareness of DT modern maize. Third, if an association is found, we test for significant differences in means across FHHs, married women, and MHHs.

Hypothesis 1 is motivated by previous research highlighting the importance of education for enabling individuals to quickly and effectively process information about new technologies (Foster and Rosenzweig 2010) and data documenting higher educational attainment of men than women in SSA (UNESCO 2015). Agricultural extension services play an important role in familiarizing farmers with new technologies, particularly at the early stages of technology dissemination, by providing farmers with information, advice, and training. The role of agricultural extension services in technology diffusion along with the consistent finding of lower access to extension services for women compared with men (Ragasa, 2014) leads to Hypothesis 2. Hypothesis 3 derives from research indicating the importance of learning from other farmers for overcoming information failures in the technology diffusion process (Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006) and research showing that men and women are embedded in different social networks (Renzulli et al, 2000; Magnan et al, 2015).

Table 1 provides descriptive statistics for the awareness model variables. A few of the explanatory variables require further explanation. We measure drought risk perception as the reported number of years in the last five in which the household experienced drought-induced maize harvest loss. Different channels through which farmers receive information and extension services included in the model are visits by and advice received from extension agents, participation in research activities (e.g. demonstration plots or field days), information received from input supply shops, interactions with other farmers, and access to electronic media messaging for production and price information. The social network variables included in the model are binary variables for communication links with kin and non-kin (friends, relatives, and progressive farmers), having at least one social network member who grew DT maize, and network diversity. Network diversity is represented by a binary variable for whether the farmer had at least one social network member from outside the village, and indicator variables for having social network members of the opposite sex as the farmer only or links with members of both sexes (reference is network members of the same sex as the farmer only).

Estimating the impact of awareness on DT maize adoption

While it is possible for a farmer to adopt a new seed variety without awareness of the traits for which it has been bred, awareness is important for widespread and sustained adoption. Measuring the effect of awareness on technology adoption is complicated by the problem of selection bias. The decision to participate in extension activities or talk with other farmers about new maize varieties is made by each individual farmer. Researchers and extension workers, meanwhile, tend to target progressive farmers first for extension activities (Diagne and Demont 2007; Kabunga et al 2012). Experiments are the best way to eliminate selection bias, but statistical methods that simulate an experimental design using observational data can reduce such bias.

We use a semiparametric technique, propensity score matching (PSM; Rosenbaum and Rubin, 1983), to measure the causal effects of the "treatment" — awareness — on DT maize adoption. PSM has recently gained interest as a method for dealing with the problem of selection bias with cross-sectional data in a non-experimental framework, without the assumptions of functional and distributional form or exogeneity of covariates. It assumes that sample selection bias can be eliminated by conditioning on observable variables, and does so by matching each farmer that is aware of DT maize with one or more non-aware farmers with similar observable characteristics. In essence, matching models simulate the conditions of an experiment in which awareness is randomly assigned, allowing for the identification of a causal link between technology awareness and adoption. PSM has been used in several impact studies of the adoption of agricultural technologies (e.g. Mendola 2007).

PSM involves three steps. First, a logit (or probit) model is used to estimate the propensity score, which is the probability of DT maize awareness. We detailed such a model in section 4.1. Second, a matching algorithm is chosen that uses the estimated propensity score to match each farmer who was aware of DT maize (the treatment group) with one or more farmers with a similar propensity score, but who was not aware (the control group). In the third step, differences in the outcome variable (DT maize adoption) are calculated for the matched treated and untreated cases, and the average of these differences is the average treatment effect on the treatment group (ATT). In the present case, the ATT represents the impact of awareness on DT maize uptake.

The first step in the PSM analysis was described in the previous section; it is estimation of the DT maize awareness model. The second step in the analysis involves matching treatment and control groups. Several matching algorithms are available to match treated and untreated groups of similar propensity scores, but the literature provides little guidance as to which algorithms work best (Morgan and Harding, 2006). We use nearest neighbor matching (NNM) with replacement, which is simple, relatively unbiased, and widely used by researchers in different fields. NNM constructs the counterfactual for each treatment case, using the control cases nearest to the treatment case on a unidimensional measure, such as the propensity score. Finally, the ATT is calculated as the difference between DT maize adoption by treatment vs. control groups.

Results

Gender differences in education, extension, and social networks

Table 1 indicates differences in education, the main sources of information on new seed, and social networks across the three groups of farmers. The average educational attainment was 3, 5.1, and 6.7 years for FHHs, wives, and MHHs. Not shown in the table are the percentages of farmers that never attended school in our sample, which were 45 percent (FHHs), 18 percent (wives), and 6 percent (MHHs). Given their higher average age, FHHs likely attended school about 20 years before the sampled married women, and 10 years before MHHs.

The percentages of respondents who had received information on new maize seed in the year prior to the survey were 30 percent (FHHs), 41 percent (wives), and 49 percent (MHHs). Extension agent visits were not a main source of information on new seed for any of the three groups of farmers. The main source of information was other farmers for FHHs, electronic media for MHHs, and both other farmers and electronic media for wives. Research and input shops appear to not reach FHHs with information on new seed, and only small numbers of MHHs and wives reported those sources of information as important for learning about new maize seed.

Table 1 shows some differences in social networks across the three groups of farmers. Men farmers (vs. women farmers) reported having more network members, especially non-kin members. There are numerical differences in the proportion of women vs. men farmers that reported having social network members who were from outside the village or that grew DT maize, but these differences are not statistically significant.

The table reveals that FHHs differ considerably from wives and MHHs in terms of age, farm size, and household size. On average, FHHs are far older and are relatively poor in land and labor resources, compared to wives and MHHs. These differences are likely to be associated with awareness and adoption of DT maize and are controlled for in the empirical analysis.

Explanatory variables	Model 1	Model 2	Model 3	Model 4	Model 5
Age (years)	-0.0056***	-0.0043**	-0.0053***	-0.0052**	-0.0039*
Main occupation farmer	-0.0403	-0.0127	-0.0286	-0.0434	-0.0391
Education (years)		0.0242***			0.0185**
Household size	0.0092	0.0087	0.0047	0.0066	0.0042
Farm size (acres)	0.0127	0.0082	0.0100	0.0042	0.0010
Drought perception	0.0174	0.0184	0.0105	0.0129	0.0089
Female head	-0.1783*	-0.1151	-0.1560*	-0.1268	-0.0562
Wife	-0.2179***	-0.1749***	-0.2087***	-0.1319*	-0.0831
Extension			0.3221**		0.2807**
Research			0.0966		
Input shops			0.2314		
Farmers			0.2179***		
Electronic media			0.3120***		0.2482***
Number of kin SNMs				0.0026	0.0030
Number of non-kin SNMs				0.0416*	0.0381*
SNM another village				0.1231*	0.1319*
SNM grew DT maize				0.5645***	0.5685***
SNMs opposite sex only				-0.0431	-0.0417
SNMs both sexes				-0.0341	-0.0543
Distance from village to tarmac (km)	-0.0049	-0.0042	-0.0052	-0.0041	-0.0042
Number DT grown in village	0.0302	0.0363	0.0400	0.0126	0.0212
Too little rain in village	0.0144	0.0036	-0.0129	0.0161	-0.0134
Kigulu county	-0.0747	-0.1068	-0.0730	-0.0650	-0.0830
Tororo county	-0.0569	-0.0788	-0.0300	-0.0536	-0.0563
West Budama county	0.1245	0.1051	0.1520	0.0941	0.0951
Bulambuli county	0.1199	0.0602	0.1195	0.1112	0.0587
N	684	682	684	684	682
pseudo R_2	0.058	0.072	0.100	0.218	0.251
Percent correct	65.8	66.5	64.8	71.0	71.0

Notes:

1. The table reports marginal effects, which indicate percentage point rather than percentage change. To arrive at percentage figures, the marginal effects must be divided by the predicted probability of DT maize awareness (0.587).
2. $^{+} p < 0.10$, $^{*} p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$

Table 2 Logit results for awareness of DT maize.

Determinants of DT maize awareness

Table 2 presents marginal effects from logit regression models. Among the control variables, only age is statistically significant ($p < 0.10$), and it has a negative association with awareness. Turning to the hypothesis tests, we begin by observing the effect on the magnitude and significance of the gender binary variables when we add variables for education, extension services, and social networks. For the base Model 1, which excludes these variables, marginal effects indicate that, compared to MHHs, FHHs and wives were, respectively, 30 percent and 35 percent less likely to be aware of DT maize. Comparing Model 1 with Models 2, 3, and 4 reveals that including variables for education, receipt of extension information, and social network characteristics reduces the absolute value and/or statistical significance of the marginal effects on the female binary variables. For FHHs, education has the greatest impact on the marginal effect, whereas for wives, social networks appear to matter most. Model 5, which includes the full set of variables, reveals that when we control for education and information access, gender is not an important determinant of technology awareness. In other words, if women farmers had equal access to education and information resources they would be equally aware of DT maize seed as men farmers.

As further testing of the study hypotheses, we assess which of the identified correlates of DT maize awareness differ based on farmer gender. Table 2 reveals that age is negatively associated with familiarity, whereas factors positively associated to awareness are education, visits from extension agents, receiving information on new maize seed from electronic media, the number of non-kin social network members, having a social network member from outside the village, and having a social network member who grew DT maize. The marginal effect for having a social network member who grew DT maize is particularly large; having such a network member is associated with a 98 percent higher probability of being aware of DT maize (see note 2 at the bottom of Table 2 for how the percentage figures are calculated based on marginal effects).

Which of the factors that are substantively and significantly associated with awareness are also correlated with gender? To address this, we refer to Table 1. Compared to MHHs, FHHs are older and less educated, have less access to electronic media for agricultural information, and have fewer non-kin SN members. There are numerical differences between FHHs and MHHs in terms of social network members from outside the village and growing DT maize, but the mean differences are not statistically significant, which might reflect low sample size. There are also differences between wives and MHHs in the factors found to correlate with awareness: wives are less educated and have fewer network members that are from outside the village and grew DT maize. As an aside, men and women farmers differ considerably in terms of the gender composition of their network members, with men mainly talking with other men about farming, whereas more than half of women farmers reported network links with someone of the opposite sex or with members of both sexes. These variables, however, are not significantly associated with awareness of DT maize.

To gain insights on which factors contribute most to explaining variation in awareness of DT maize among farmers, we employ a Shapley decomposition (Shorrocks 2013). Figure 1 shows the percentage of the structural probit model's goodness of fit (pseudo-R2) that can be attributed to different sets of explanatory variables. The pseudo R-squared values reported at the bottom of Table 2 are somewhat low, but not worrisome. R-squared properties do not carry over to nonlinear regression (Cameron and Trivedi 2010). Of course, the factors explored in the empirical models do not exhaust the possible explanations for variation in DT maize awareness. There are variables which theory suggests are important but which are not available in our dataset, such as variables measuring motivation and cognitive ability.

With these caveats in mind, we turn to the Shapley decomposition results (Figure 1). The social network variables are by far the most important, explaining 66 percent of the model's fit (i.e. pseudo-R^2), while corresponding figures for education and extension services are 8 percent and 11 percent, respectively. Farmer gender accounts for less than 5 percent of the variation in awareness of DT maize, once we have controlled for other important factors as in Model 5. By comparison, 46 percent of the variation in DT maize awareness explained by Model 1 is related to gender of the farmer (results not shown but available upon request).

The next section proceeds to measure the impact of awareness on DT maize adoption to gain insights on whether the observed gender gap in adoption partly reflects differential awareness of the technology among women and men farmers.

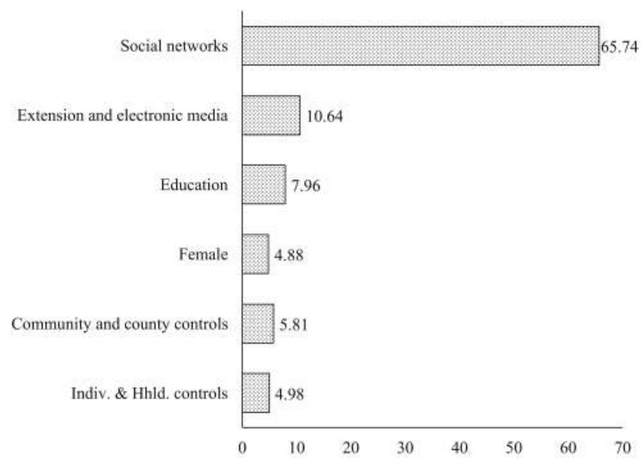

Figure 1 Relative importance of factors that explain farmer awareness of DT maize, CIMMYT Uganda Survey 2014.

The average treatment effect on the treated (ATT)

Table 3 presents the estimated differences in DT maize adoption among farmers who were aware and those who were not aware. The measured impacts are very large: otherwise similar farmers who were aware and those who were not aware of DT maize had adoption rates of 24.2 percent and 1.2 percent, respectively. The estimated impact of awareness on adoption is 22.9 percentage points, indicating that awareness of DT maize is an important condition for adoption, and highlighting the need for awareness creation to stimulate adoption of DT maize seed.

	Coefficient	t-statistic
Potential Outcome Means, Treated	0.242	--
Potential Outcome Means, Controls	0.012	--
Impact (Average Treatment Effect on Treated - ATT)	0.229	4.63

Table 3 The impact of DT maize awareness on DT maize adoption.

Discussion and Conclusions

This study analyzed gender-based differences in awareness of new multiple stress-tolerant, high-yielding maize seed developed under the Drought Tolerant Maize for Africa (DTMA) project and referred to as drought-tolerant (DT) maize. Adoption per se is not such a big issue for DT maize in Uganda. The major issue addressed in this paper is the differential adoption and awareness rates between men and women. Our study shows that initial uptake of this emerging technology is marked by a significant gender gap: In the 2014 major season, 29.2 percent of surveyed male household heads (MHHs) grew DT maize varieties; corresponding figures for female household heads (FHHs) and wives in spousal couple households were 5.3 percent and 11.1 percent, respectively. Propensity score matching was used to evaluate the importance of awareness of the technology for its adoption. We found that farmers who were aware of the technology had a much higher probability of adoption (22.9 percentage points), suggesting that increasing awareness is important to increase adoption.

Our survey also reveals a gender gap in DT maize awareness: 43.3 percent of FHHs, 51.0 percent of wives, and 67.6 percent of MHHs were familiar with the technology. Understanding gender-based differences in awareness is important to understanding why women (vs. men) have lower rates of DT maize adoption, since awareness is important for adoption. Results of logit analysis (Table 2) supported the study hypotheses that gender-based differences in educational attainment, access to extension services and the characteristics of social networks account for the observed differences in awareness of DT maize.

Female farmers, particularly FHHs, have much lower educational attainment than male farmers (Table 1), and DT maize awareness was found to increase with education (Table 2). DT maize is a technology that is not difficult to decipher, and a farmer who can read seed packet labels and calculate profit and loss should be able to understand the benefits of adoption. A farmer who has completed or attended several years of primary school should have sufficient reading, writing, and basic math skills for awareness and adoption of DT maize. At the Uganda study sites, however, many FHHs and some wives and MHHs do not have sufficient literacy and numeracy skills to decode DT maize on their own. For these farmers, particularly, agricultural extension and social network links can play essential roles in generating technology awareness.

The regression analysis revealed that extension agent visits and electronic media were strong predictors of DT maize awareness. The percentages of farmers reporting extension agent visits in the previous year was essentially the same and very low for both sexes. Women, especially FHHs, were less likely than men to report electronic media as a main source of agricultural information. Gender-based differences in social networks were strong predictors of DT maize awareness, and the most influential social network characteristics were having social network members that are non-kin, from outside the village of residence, and who grew DT maize previous year. When education, information resources, and social network characteristics were controlled for, gender had no significant association with DT maize awareness.

The results of this study have implications for the design of well-targeted, socially-equitable policies that influence the adoption of climate-smart agricultural technologies. Women farmers need improved access to educational opportunities, information resources, and communication technologies to ensure they are aware of new technologies and have a good understanding of the benefits they offer. Toward this end, agricultural extension programs (e.g., farmer-to-farmer extension and agricultural voice radio), seed company promotional activities, and adult literacy and numeracy programs should deliberately target their activities to women farmers, seek ways to overcome constraints to women's participation, and modify their messages to be more useful to women as food producers. A starting point in persuading extension workers, seed company personnel, and literacy/numeracy program staff of the high importance of reaching women farmers is to address the common misperception that "women are not farmers" (Ragasa 2014). Gender mainstreaming could also be pursued by hiring more female personnel and selecting more women as the farmers who manage DT maize demonstration plots and provide other farmers with advice and information. Our results also suggest the importance of having these lead farmers target women farmers as their followers and reach out to women and men farmers in other villages with information on DT maize seed.

Acknowledgements

This work was done under the Drought Tolerant Maize for Africa (DTMA) project, funded by the Bill & Melinda Gates Foundation, and implemented by the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute for Tropical Agriculture (IITA). Data used in the study were collected while the lead author was a Senior Scientist and the second author a Consultant at CIMMYT. The authors wish to thank Woinishet Asnake, Mywish Maredia, Godfrey Asea, and the outstanding team of field supervisors and enumerators for collaboration on the design and implementation of the Uganda survey. Many thanks are due to our respondents at the study sites. The contents and opinions expressed herein are those of the authors and do not necessarily reflect the views of the associated and/or supporting institutions. The usual disclaimer applies.

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