Seed choice and misinformation among smallholder farmers in Africa

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***Abstract**: Despite decades of research and interventions, crop yields for smallholder farmers in sub-Saharan Africa are dramatically lower than yields in more developed countries. Attempts to address variable yields of staple crops in Africa since the Green Revolution through policies and investments in advanced seed cultivars have had mixed results. Numerous African countries have doubled down on hybrid varieties of cultivars through government subsidy programs and investments in research and seed multiplication. One possible explanation for why these programs have not resulted in more significant yield improvements is the challenge faced by farmers to select cultivars that are suited to their local agro-ecological conditions. The question of what seeds farmers choose to plant is a deceptively complex topic as it is often affected by social norms, local availability, and the availability of information on seed performance and agricultural extension to support farmers. At the foundation of this decision is how farmers perceive attributes of different seed varieties and how that is impacted by their perceptions of drought and rainfall variability and management decisions such as when to plant. We demonstrate how paternalistic policies, an overabundance of seed choice coupled with a dearth of information, have resulted in a complex decision matrix for farmers and in many cases unfavorable crop production outcomes.*

***Keywords**: climate change, drought, perceptions, uncertainty, maize, Africa, Zambia.*

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1. INTRODUCTION: HYBRID MAIZE AND INPUT SUBSIDIES IN AFRICA

The Green Revolution in Asia during the 1960s was based on the development of high-yielding varieties of staple crops that were responsive to fertilizer (Evenson and Golin, 2003). During this period average yields of rice and wheat doubled although most of the gains were in irrigated areas and areas with high rainfall. Although grain production has increased, Africa is still struggling to achieve its Green Revolution. Since the initiation of market reforms in sub-Saharan Africa in the 1970s and 1980s, numerous African governments have responded to food deficits by implementing costly and ambitious fertilizer and hybrid maize subsidy programs with some success (Denning et al., 2009; Mason et al., 2013).

Maize is the dominant staple crop in Africa, now grown by the vast majority of households in some countries and continues to be the target of breeding programs in the region. Investment in the maize sector and associated institutions established during the colonial period led to maize breeding success in countries like Kenya and Zimbabwe, particularly during the 1970s and 1980's (Smale and Jayne, 2003). Innovations in technology, policies, institutions, and especially breeding improved germplasm was at the core of this success. Coupled with improved germplasm were investments in extension, seed distribution, delivery, fertilizer subsidies, delivery, and access to credit.

In recent years, numerous countries in Sub-Saharan Africa (SSA) including Ethiopia, Ghana, Kenya, Malawi, Nigeria, Tanzania, and Zambia have all implemented input subsidy programs at substantial cost to government and donor budgets (Mason and Gilbert, 2013). Fertilizer subsidy programs have existed in almost every year for decades in Malawi and Zambia. The majority of these programs focused on providing inorganic fertilizer and improved maize seed to small farmers at below market rates although many of them also expanded to provide subsidized seeds, particularly hybrid maize seeds. While the majority of countries experienced a decline in absolute maize production during the 1990s, others (such as Malawi) experienced an increase due to input support programs (Smale and Jayne, 2003).

In addition to doubling or tripling the yield of traditional landraces, breeders have also developed varieties resistance to certain pests and more tolerant to meteorological drought and periods of low rainfall during the growing season. Some hybrids are so well adapted they can outperform local varieties under low input and management systems on low fertility plots even during a drought year (Heisey and Smale, 1995). Maize breeders also began to develop maize hybrids with shorter maturation period to fit into shorter and more erratic growing seasons that were effectively tolerant of late planting (Smale et al.

2015). Shorter-season hybrids are particularly critical in rainfed areas of SSA characterized by a single growing season per year where farmers have labor shortages and plant local maize and other crops first.

Farmers are still struggling to achieve yields above three tons per hectare in SSA (compared to an average of about 10 tons/hectare in the US) despite this proliferation of hybrid maize and fertilizer subsidy programs. There has been an influx of hybrid maize with rapid turnover of varieties and overuse of other hybrid varieties beyond obsolescence. With a near absence of agricultural extension in Africa and very little information and a lot of marketing of very similar varieties, farmers are inundated with numerous similar choices and an inherently complex decision-making context. There has been little work investigating the process by which farmers use alternative decision-strategies for seed cultivar choice and planting date. Previous research has not unpacked the complexity inherent in the selection of hybrid maize seed cultivars by farmers in the context of the variety of choices available to farmers and farmers' perceptions of a changing climate.

2. BACKGROUND: HYBRID MAIZE SEED CHOICE IN ZAMBIA

While there was some hybrid seed being imported from Zimbabwe during colonial times, the maize seed industry in Zambia was formalized with the establishment of the Zambian Seed Company (Zamseed) in 1981 (Morris et al. 1998; Smale et al., 2015). Zamseed was organized as a parastatal to replicate seed varieties, mostly maize, developed by the National Agricultural Research Service (NARS). Maize breeders started breeding shorter-season hybrids that were tolerant of late planting. The new varieties combined with subsidized credit for seed and fertilizer led to a doubling of maize area in the 1970s and 1980s (Smale et al., 2015).

The seed market was liberalized in the 1990s as a result of pressure from the International Monetary Fund and the World Bank through the Structural Adjustment Program. During this process, Zamseed was privatized, and many new seed companies entered the market. The number of hybrids and improved OPVs doubled between 1992 and 1996 (Howard and Mungoma, 1997). Since then hundreds of new varieties have been released in Zambia by 14 different companies, and the rights of almost all these varieties are held by private seed companies (Smale et al., 2015).

At the same time the government of Zambia was building a subsidy program that heavily focused on hybrid maize and fertilizer. During Zambia's 51 years of independence there was only a brief period in the early 1990s where there were no agricultural subsidies in Zambia (Mason et al., 2013). Prior to liberalization, the government of Zambia through the parastatal National Agricultural Marketing Board (NAMBOARD) provided farmers with subsidized fertilizer and seed on credit and purchased their harvest at a pan-territorial and pan-seasonal price (Smale and Jayne, 2003). During liberalization, the government abandoned NAMBOARD due to its high operational costs but found it politically infeasible to stop subsidies. The Fertilizer Credit Program (FCP) was started in 1997, reached a limited number of beneficiaries and was effectively an input loan that was to be paid back at the end of the season. However, loan default was high and the FCP morphed into the Fertilizer Support Program (FSP) in 2002, a large scale fertilizer subsidy program distributed by input suppliers (as opposed to through agrodealers) (Mason et al, 2013). The name was changed to the Farmer Input Support program (FISP) in 2009 but the goal remained the same.

Through investment, liberalization, and subsidies the Government of Zambia effectively institutionalized hybrid maize production among small-scale farmers in Zambia over the last few decades. In the process, farmers who were stripped of decision-making capacity now suddenly found themselves inundated with choices (depicted in figure 3). The development and dissemination of hybrid seeds in Zambia went from a single company in the 1980s to numerous national, regional, and international private seed companies (see Figure 3). These seed companies submit newly developed varieties to the Seed Certification and Control Institute (SCCI) who evaluates the seeds on research stations across Zambia for two years. The Variety Release Committee comprised of various government and non-government stakeholders decide which seeds should be certified, and then they are released to farmers. Varieties traditionally reached farmers through the FISP (orange pathway in figure 3). With the introduction of an electronic voucher component to FISP implemented in the 2015-2016 season, farmers are able to choose any seed available on the market. With the e-voucher program hybrid seed choice is filtered by SCCI and the VRC but then directly connects agrodealers (agricultural goods suppliers) to farmers (blue pathway in figure 3).

Originally FISP allocated maize varieties to farmers that were members of participating cooperatives based on an assessment of agroecological suitability made by the FISP (without farmer choice). These varieties were targeted to various regions based loosely on agroecological needs and the seed and fertilizer was delivered directly to the cooperatives. Gradually FISP allowed farmers to choose between more varieties of hybrid maize and gradually offered more seed variety choice to farmers each year. With the introduction of the e-voucher program in the 2015- 2016 season (rolled out in select districts) farmers are now able to choose from any hybrid maize seeds available from agrodealers on the market. Participating farmers are permitted to use their allocated funds to purchase other agricultural inputs such as veterinary supplies and plows.

Farmers are now inundated with a large volume of seeds to choose from with very little agricultural extension to help them determine which seed varieties will work best on their farms. Most of the information they now get on seed varieties comes from three sources; a) other farmers, b) directly from the seed companies through advertisements, crop trials on lead farmers' fields and c) through pamphlets and information obtained through the agrodealers who sell the seeds. We explore seed choice and misinformation by examining the following questions: Are farmers' perceptions of hybrid maize seed varieties the same as seed companies? Do farmers make good decisions about seed selection with respect to the timing of planting? What factors determine the choice of maize cultivars and to what extent do farmers' perceptions of hybrids matter? We address these research questions in the context of smallholder agriculture in Zambia.

3. STUDY AREA

Zambia is a dryland ecosystem and the majority of farming is rainfed agricultural production with relatively little irrigation. There are three agroecological zones in Zambia and average annual rainfall varies from 800 to 1200 mm/year depending on the region within Zambia. This study took place in Choma district, which is one of 13 districts that comprise Southern Province and is partially in the driest agroecological zone in the country (see figure 1 below). Choma district falls within agro ecological Zones I and II. The southeast portion that falls into Zone 1 is a low rainfall area and one of the hottest and driest regions of the country. The soils tend to be sandier and the soil fertility is poor. Zone II is characterized as a medium rainfall belt with relatively good soils and slightly more rainfall than Zone 1.

<insert Figures 1a and 1b. Figure 1a. Map of study area- shows location of respondents in SP, agroecozones, inset in a map of Zambia. Figure 1b. length and location of longest dryspells (on another map side by side) >

Sample

Household level surveys were conducted between October 14 and November 10, 2016 prior to the arrival of the rains. Survey questions focused on basic socioeconomic data, production data from the previous season (2014/5), and perceptions of rainfall, and previous experiences with extreme weather events. We sampled households from every camp (the next smallest administrative unit) within Choma district (12 camps total). We contacted camp officers (similar to agriculture extension agents) and asked them to contact a community chairperson who invited an equal number of male and female farmers to a group meeting at a central location. We then randomly selected one-third of this group to participate in the survey for a total of 248 farmers.

Table 1 provides descriptive statistics of the population. Sixty-two percent of the sample was men with an average age of 45. Households in our sample had 8 household members on average, 3.7 of which were children, 2.65 were young adults, and 0.26 were over 65. Six out of the eight household members were working on the farm and 3.41 were male laborers. The average respondent completed some secondary school and the highest average education level in the household was completing secondary school.

<insert table 1 here: descriptive statistics>

Precipitation and planting dates

In Zambia there is a distinct growing season from roughly November to April. Figure 2 depicts weekly precipitation over the growing season in Choma. Daily precipitation data used in this paper comes from a weather station in Mochipapa, outside of the district town of Choma. The planting dates for farmers' primary plantings varied from early November until the end of December. Nearly one-third of farmers planted some maize field during the week of Dec.1, which is more than one month later than their usual planting date.

<insert Figure 2. Daily precipitation and planting dates in Choma, Zambia during the 2014-5 season>

Intermittent periods of no or low rain are common—such as the dryspell that occurred during the first three weeks of March in the 2014/5 season. Dryspells sometimes result in total crop loss or require replanting. Most traditional varieties of maize generally take five to six months to reach maturity so farmers need to utilize the entire rainy season to produce them. Early and medium maturing varieties are critical in areas when a given rainy season is shorter than six months or characterized by dryspells. The majority of farmed land is allocated to maize (more than 80%) while a diversity of other crops is grown on a much smaller scale.

Figure 1b depicts the spatial dispersion of the length of the longest dryspells during the 2014/5 season among the sample population in Choma. In the 2014/5 season dry spells were ubiquitous with most farmers reporting dryspells between 14 and 30 days. The largest share of respondents reported the longest dryspell lasted 30 days. Reporting of the dry spells was relatively dispersed too, with dryspells of different lengths reported within close proximity. This demonstrates that microclimates are common and microclimatic variation may be a more significant determinant of farmer seed choices than previously thought.

4. RESULTS

4.1 Seed choice

The following section describes seed choice within the FISP, the seeds chosen by the sample of farmers in Southern district and their attributes as defined by farmers and seed companies. We then look at farmers' planting dates and the impact of planting dates on maize yield by seed maturity class.

FISP and seed choice

During the 2014-2015 growing season in Zambia, the FISP provided farmers with subsidized agricultural inputs including hybrid maize seed and inorganic fertilizer through membership in a local agricultural cooperative. In its initial incarnation, registered farmers received inputs to cultivate two hectares of maize: 400 kilograms of fertilizer and 20 kilograms of hybrid maize seed and under the current iteration they receive half that amount or the monetary equivalent if they use an e-voucher. While FISP originally had very limited options of maize seed varieties (2 in 2014) they have been increasing the choice of seeds available to farmers. In 2015 farmers in a set of pilot districts were able to choose their seed variety from the agrodealers using an electronic voucher as well as other inputs such as horticultural and crop seeds, livestock vaccinations, and fingerlings.

In the 2014/5 growing season farmers cultivated a total of 30 different varieties of maize. Of these, 22 varieties were reported as acquired through the FISP. There were seven "local" (or non-hybrid) maize varieties reported. Of the 14 seed companies currently producing hybrid maize in Zambia six were planted by farmers in the sample: Dekalb (DK), MRI Seed Zambia (MRI), Pannar Seed (PAN), Pioneer (PBB), SeedCo (SC), and Zamseed (ZMS). No single seed company dominated in Southern province and the seven most popular varieties were all from different seed companies. The maturity period of these varieties ranged from very early to late maturing. Local varieties are not shown in the table.

<insert table 3. Seed varieties cultivated and relevant attributes>

There were only two plantings of late maturing hybrid varieties out of the entire sample of 450 plantings. The majority of farmers planted early or medium maturing varieties. Thirty-eight plantings of local maize were reported (not included in the table). There is an overlapping range in classification/days to maturity (Very early: 105-125; early: 110-130; medium: 120-136; and late:140-148). Very early to early are only five days different on either end with 15 days of overlap. Early and medium also overlap by 10 days. There is also a positive relationship between yield potential of a seed variety and duration (days to maturity). Logically, the longer the maize plant is in the field the higher the yield is expected to be, not accounting for any dryspells. And there is also a clear relationship where the seed price increases with the duration and yield potential.

Perceptions of seed attributes

Table 3 also presents the mean values of the attributes associated with the hybrid varieties farmers are the most familiar with. Each attribute has a value of 1 if the farmer stated that the given attribute was a positive characteristic of the crop, and 0 otherwise. The mean value is the percentage of farmers whom associate each attribute with the seed variety they chose. These percentages can be roughly interpreted as the marginal utility of choosing a variety because of that attribute.

<insert table 3 about here>

The most common attribute associated with any variety was whether there was good availability of seed. High yield is also of course important to farmers, as is the performance of the variety in an intercrop. Consumption attributes are also important to farmers including taste and poundability; or how easy it is to pound the maize into a powder that is used to make the traditional maize meal dish (nsima). Storability is also important to farmers. Resistance to pests and drought are important production characteristics. Seed quantity requirements and seed costs are the least cited attributes by farmers.

Figure 4 depicts the difference between how farmers and seed companies classify hybrid varieties. There are numerous reasons why farmers may perceive varieties to be different than seed companies. Primarily, varieties may perform differently on farmers' fields and on different soil types and in less fertile soils than they did in crop trials run by seed companies or SCCI. The overlap in the duration classification of seed varieties is apparent in figure 4. This is consistent with the wide range in the maturity classifications (days to maturity) given by the seed companies to the hybrid maize varieties (seen in figure 3). Farmers in Choma district perceive medium maturing varieties to be earlier maturing on average than seed companies. Farmers view early maturing varieties as later than the seed company's classifications. Taken together there is a normalizing trend to the perceptions with most varieties falling on average between early and medium maturity albeit with little difference between them. This figure demonstrates a clear mismatch between farmers' perceptions of the varieties and seed company's classifications of the average days to maturity.

<insert figure 4 here>

Impact of late planting

The blurring of variety classification also bears out in farmer's actual management practices. The distribution of planting dates is extremely similar across classification. For all classes there is a relatively normal distribution of planting dates centered around December 1. Farmers are planting varieties at the same time, regardless of the seed company's designation of maturity class. This is particularly troubling with farmers on the right tail of the distribution for medium maturing and local varieties who are planting them well into December. Planting this late in the season decreases the likelihood that the rainy season will be sufficient to meet crop needs. Late planting also puts farmers at risk of crop loss to dry spells without sufficient time to replant a new crop.

<insert figure 5>

The 2014-2015 growing season illustrates the pitfalls of late planting well since there was a significant dry spell late in the season. Recall that in figure 2 demonstrates that the Mochipapa station reported zero rainfall between March 3 and April 1. A dryspell late in the season is not likely to impact very early and early maturing varieties that were planted at the beginning of the rainy season (in November). Drought stress from dry spells are likely to have a larger yield impact on plantings that took place in December. Drought stress is mostly related to insufficient moisture in the 4-week period around tasseling, so varieties that were planted approximately 60+/-28 days before the dryspell (depending on the duration) are most likely to be impacted. This suggests that any variety planted in December is likely to be the most affected.

<insert figure 6 here>

In a normal year (without dryspells), yield per hectare is relatively consistent across the season. However, given the length and spatial distribution of the dryspells we would expect maize yield across southern province to be heavily impacted and to decrease with the planting date. Figure 6 demonstrates that median yield of maize decreases with planting date. Medium and late maturing varieties are more impacted than very early and early maturing varieties on average (see figure 7).

<insert figure 7 here>

4.2 Determinants of maize seed choice

In this section we describe a model that examines the determinants of hybrid maize seed choice. We pay particular attention to farmers' perceptions of the frequency of climate events, the likelihood of future climate events, and their perception of the impact of drought on local versus hybrid varieties of maize.

Regression model

In order to understand the determinants of seed choice we used a binary logistic regression model of whether a farmer had planted any variety that is classified as a very early, early, medium maturing hybrid or is a local variety (local varieties appear to cover a range of well adapted open pollinated varieties and local land races). The categories of predictive factors include a vector of variables that characterize farmers' perceptions of rainfall uncertainty, a vector of socio-demographic characteristics, and a vector of management decisions such as planting date and diversity of maize plantings on the farm.

The explanatory variables related to perceptions include a) their optimism about next year's rains (a categorical variable representing optimist, realist, pessimist, and "I don't know"), b) their perceptions of the probability of climatic events expressed as their expectation of the frequency of occurrence of an event converted into a probability, and c) their expectation of yield advantages of hybrid compared to local maize under normal conditions, low rainfall, and late planting. We also include variables that characterize farmers' previous experiences with low and high rainfall events.

Socioeconomic variables include age, education, family size, and farm size. We also include distance to markets where agricultural inputs are purchased as a geographical variable. Based on the household asset data we constructed an asset index using a procedure similar to that developed by the Demographic and Health Surveys (DHS) Program and the World Bank (Rutsein and Johnson, 2004) and off-farm income. The index is calculated based on household ownership of key assets that were owned by more than 5% or less than 95% of the households and is the first principal component from a principal component analysis (PCA) (Filmer & Pritchett, 2001). Each household asset for which information is collected is assigned a factor score generated through the PCA giving us a scale of continuous wealth for the households. The factor score or first principle component is then ranked from high to low and this variable is divided into quintiles. We also include a set of variables looking at their access to information and assistance: whether or not they were part of an agricultural cooperative and whether they participated in the FISP program last year.

Perceptions variables

We asked questions to gauge farmers' optimism about future rains. Specifically, we asked, "How will the rain next year compare to the 2014-2015 growing season?" Forty-one percent of the sample believed that there would be more rains in the coming year, 33% believe they will be the same, and 17% believed they would be less than the previous year. Nine percent of farmers reported, "I don't know" how the rains will compare to the previous season.

We also characterized farmers' perceptions of the performance of hybrid maize varieties compared to local varieties during a normal year, a year with dryspells, and a year when the rains were late and planting was delayed until January 1 (see figure 7). It has been argued that hybrids perform worse under conditions of low fertility or abiotic stresses, including drought and flooding (Friis-Hansen, 1989). But other research has found that hybrid crops on average actually perform better than local landraces under stressful growing conditions (Heisey and Smale, 1995). To understand how farmers perceive this difference we asked them if they planted 20 kg of local or hybrid maize seed on a given date (Dec 1 or Jan 1.), what would they expect the harvest to be? Farmers in this sample perceive hybrids to roughly perform twice as well as local maize across all scenarios, if not slightly better under dry spells and late rains. Very few of the Zambian hybrids are considered by seed companies to be drought tolerant varieties so it is surprising farmers would perceive them to be resilient under dryspells. Since many of the hybrids on the market are bred for early maturation it makes sense that farmers perceive them to outperform local maize when planted late.

<insert Figure 8. Perceived yield of 20 kg of local versus hybrid maize seed with different planting dates (under various conditions)>

Previous experience with climatic events is also likely to influence one's perception of future climate event occurrence and thus the level of uncertainty when making maize seed choices. We asked respondents if floods, drought, or dryspells had affected their household in the past 6 years. Floods affected 9% of respondents, drought affected 18%, and dry spells affected 83% respondents. We also asked farmers the frequency they believe they experience a high rainfall or drought year (see figure 8).

High rainfall years were more widely dispersed with the majority of farmers reporting between 2-5 years and the rest spread out to over 10 years. Experience with drought was much more bifurcated with approximately half the farmers reporting less than 5 years and the other half reporting more than 10 years.

<insert Figure 9. Farmers' expectations of a drought, high rainfall and normal year>

Determinants of seed choice

We estimated four binary logistic regression models of the odds of planting very early, early, medium, and local varieties on a given farm as described above. Only two farmers planted late maturing hybrids so we omitted those from the statistical analysis. The odds of planting a very early hybrid maize variety are higher if farmers are less educated. The odds of planting an early variety are higher if the farmer planted at a later date (the odds of planting an early variety increase x percent every week). Perceptions influenced the decision to plant an early maturing variety: if a farmer was less optimistic about the coming rain, had previous experience with dryspells, or perceived the rains to start earlier in the 2013/4 season (the odds of planting an early variety decrease x percent every week). These farmers tended to be older, less educated, poorer, more off farm income.

<insert table 4>

Farmers who planted medium maturing varieties perceived the rains to start later in the last season (2013/4 season). These farmers were on average more educated and had been recipients of FISP (which tends to give out medium maturing hybrids).

Farmers who planted a local variety planted their maize at a later date on average. They perceived hybrids to be more impacted by dryspells. These farmers tended to be further from roads and less likely to have titled land (land tenure).

5. DISCUSSION

Seed choice and misinformation

The proliferation of hybrid maize adoption in Zambia is intertwined with the history of institutions and policies promoting hybrid maize. Liberalization of the seed market has flooded Zambian farmers with hybrid maize seed choices and the use of e-vouchers now allows them to choose what they want. With this backdrop we find heterogeneity in preferences and little consensus between farmers and seed companies on the attributes of the varieties, particularly in terms of the maturity period. While there is a wide selection of hybrid maize varieties available to farmers, there is little information available to them about the varieties. It is likely that farmers pay attention to what seeds have done well for friends and neighbors but not to recommended management practices. Another explanation is that there is so much climatic variation and drought stress in dryland parts of Africa so within a district a single seed variety can have a range of responses, particularly in terms of the number of days to maturity. If there is ambiguity about the maturity period of a seed variety than seed maturity classifications are not that meaningful. The unpredictability of the rainfall and the poor growing conditions compound the confusion created by the overabundance of seed choice.

High yield is one of the most cited and important noted attributes of seed varieties as expected but farmers are also selecting varieties for myriad reasons. Numerous other studies have confirmed the importance of both production and consumption attributes to subsistence farmers in developing countries (Waldman et al., 2014; Ortega et al. 2016). Pest and drought resistance are important production attributes to farmers but are not often advertised effectively. According to SCCI records, few hybrid varieties are explicitly characterized as “drought tolerant” varieties in Zambia and in low rainfall areas like Choma district all maize varieties must be drought tolerant to some extent. Storing maize is a major challenge across Africa (Thamaga-Chitja, 2004) and hybrids tend to have greater than 40% loss in gross yields which is much higher than local landraces on average (Smale et al., 1991).

There is some evidence that the availability of seed is a more significant predictor of what seed varieties farmers select than their preferences for specific seed varieties or attributes. Some maize varieties have historically been more available than others because they are disseminated through government run programs and there may be a path dependency related to those varieties. While a variety typically does not remain in production for more than six years, seed companies frequently introduce and market new and improved versions of previous varieties (i.e. SeedCo 606 being a slightly modified version of SeedCo 604) and this marketing strategy provides some level of comfort to a farmer if they have had good experience with the 'parent' seed of a new variety. Regardless, the number of seed varieties available to farmers still varies as a function of remoteness. Given that few smallholders have mechanized sources of personal transportation, farmers in remote areas are do not have access to as broad a range of hybrid seeds as farmers closer to urban areas. This in effect may result in farmers planting the seed varieties that simply are available to them despite a preference for a different variety.

Are farmers making good planting decisions with the varieties (timing of planting)?

Farmers employed a wide variety of planting dates in the 2014/5 season. It is apparent from the data collected here that the planting date is crucial to yield success with varying duration of maize hybrids—illustrated by data from the 2014/5 growing season, which was a bad rainfall year in Zambia. Minimizing the amount of time a maize crop is in the field is the major contribution of early maturing hybrids. They allow farmers to cope with the myriad reasons why they might be forced to "late plant". One common narrative is that there are household labor shortages and so farmers are not able to get their crops planted as early as they would like. Many households also prioritize household food crops including local varieties of maize over hybrid maize varieties since local varieties are more often preferred (anecdotally) for consumption. While seed companies may consider varieties to be "drought resistant" without soil moisture from rainfall there is little opportunity to plant earlier than most farmers end up planting.

There is high heterogeneity in environmental conditions at the national, provincial, district and even farm level in Zambia. The upper plateau of the Southern Province has relatively little topography, but even micro-topographic factors can mean that two fields within a small spatial area have different levels of soil moisture. A farmer with land holdings in different topographic contexts will be more likely to plant different seed varieties given that a lowland area can be planted earlier than an upland area. If a field can be planted earlier, then it would make more sense to plant a late maturing variety that matures over six months and provides a better yield than an early maturing variety that matures over three to four months. For farmers without access to irrigation which is roughly 99% of the population of Choma district they are unable to plant before the rainy season begins, which can be as late as two months into the growing season. A farmer would be unlikely to plant upland or low moisture fields with a later maturing variety this late into the season. Thus if a farmer has to wait until two months into the growing season to plant a field, then that farmer would be more likely to plant a variety that can mature in four months.

In SeedCo's agronomy manual they show a figure depicting a declining impact of planting date on maize yield and state that the later the maize is planted, the lower the yield. This is consistent with the impact of late planting on average yield that we found. However, the SeedCo graph assumes that farmers can plant as early as the beginning of October which would suggest they have access to irrigation and are planting late maturing hybrids early in the season. The reality is that in a typical year in a low rainfall rainfed system like southern Zambia neither "early planting" nor late maturing hybrids are feasible and so the impact of planting date on yield is minimal. There is evidence from the regressions that farmers who are planting later in the season are more likely to plant early maturing hybrids but there is also evidence that they are planting local varieties on a later date. Planting date was not significant for medium maturing varieties which indicates that farmers are not strategically planting hybrids across the board. There were substantial delays in the rollout of FISP and many farmers received their funding later than they would have liked to plant and this may also impact planting date.

What factors drive the choice of hybrid cultivars? (Or how do perceptions and biases influence seed choice?)

Risk perception appears to play an important role in cultivar choice. Past experiences with drought and flood as well as perceptions and uncertainty about future climate events influence maize seed choice, which aligns with prior research (Slovic and Weber, 2002). Many farmers appear to have fallen into a rut and expect the rains to come at a certain time each year, which implies status quo bias (Samuelson & Zeckhauser, 1988; Kahneman *et al*., 1991). It is also very likely that many farmers make their purchases or seed variety choice prior to the rains actually arriving. These types of biases may play a substantial impact in depressing maize yield. If farmers are optimistic about the future rains they may be more willing to take a risk and plant medium maturing hybrid varieties given the higher yield payoffs, before knowing the planting date. This is likely more of an issue for farmers who live far from markets and agrodealers who are not able to wait for the rains to purchase seeds. Many farmers may be ordering the seeds for delivery or through their cooperatives who coordinate purchasing and transport prior to the rainy season onset.

Similarly, farmers' perceptions may be shaped by their past experiences, particularly dry spells which are the most common weather related events to impact yield. If a farmer had a bad experience with dryspells in the past they may become more risk averse (Slovic et al., 1986). There is evidence of this in the regression results, where farmers who were impacted by dryspells in the past were more likely to plant early maturing varieties. This is risk aversion in the sense that they are willing to accept the lower maize yield potential of an early maturing hybrid if it means they can avoid the risk of having the maize in the field longer which exposes them to a higher probability of being impacted by a dry spell. In the absence of irrigation, choosing a seed variety is thus based on ones' expectations about the rainy season as opposed to just agronomic potential.

This is also true of one's perception of the onset of the rainy season. The later one perceives the rains started in the past impacts the choice they made in the present season. The odds of planting an early variety decrease each week a farmer perceived to start in the past. When they perceive the rains to start each year is a function of when they actually start and some level of memory bias. If they do not think the rains are long enough to plant medium maturing varieties, they will see no benefit in planting medium maturing varieties. This is evidence of another dimension of risk aversion.

Another key part of the seed choice story is total size and distribution of land holdings and hence number of plantings. A farmer with more land holdings has more potential to experiment with new varieties and to distribute risk by planting both early and medium maturing varieties. Zambia has relatively large average size of land holdings compared to other countries in sub-Saharan Africa, but still many farmers have land holdings that are only marginally sufficient to produce enough food for their household's food needs. Support for this hypothesis is seen in the significance in the number of seed varieties a household planted. Diversifying the type of seed through multiple maize plantings is a way of spreading risk.

6. CONCLUSIONS

The choice of maize seed type is an important decision for farmers on the brink of food insecurity in Africa. Now that many African farmers are flooded with choices it is critical that they understand the tradeoffs involved in their crop decisions. Although we may expect that more choice leads to more satisfaction, too much choice can lead to indecision and demotivation (Iyengar and Lepper, 2000). A government body overseeing certification and release of new hybrid seeds is an important component of controlling for seed quality in Africa but there is a lot of information that needs to be conveyed to farmers about new varieties. Allowing farmers to have greater choice of hybrid maize seed variety through the new e-voucher system theoretically presents farmers with the ability to seek out varieties that fit into their cropping systems more effectively thus reducing exposure to risk. However, an overabundance of choice, a mismatch in perceptions of duration between farmers and seed companies, and wide heterogeneity in performance of very similar varieties diminishes the clarity of seed choice for farmers.

The choice of planting dates is crucial with varying duration of hybrids—illustrated by this sample of farmers in the 2014-2015 growing season in Zambia, which was a bad rainfall year. Numerous factors lead farmers to make risk averse cropping decisions which limit the positive impact of having greater seed choice. We found evidence that people plant early maturing varieties because of pessimism about rains, earlier onset of rains, and experience with drought. Early maturing hybrids may lack the yield potential of medium or late maturing hybrids and choosing early maturing varieties limits farmers yield potential but reduces their risk. Still early maturing varieties appear to have higher yields than local landraces and may be a better option for farmers. Socioeconomic factors like education, access, land security and wealth may lead farmers to be stuck with local landraces. In summary, farmers may not be trying to maximize yield as much as trying to mitigate against calamitous crop failure.

Hybrid maize has gradually become the prevalent staple crop in Zambia bolstered by decades of government investment in breeding and input subsidy programs. The institutionalization of hybrid maize has largely been a top-down process and is now cultivated by greater than 80% of Zambian farmers, the most of any other African country. Throughout this process, FISP has had limited success in raising yields (Mason et al. 2013; Sitko et al., 2012; Resnick and Mason, 2016). Programs like FISP promote adoption of hybrid maize despite variable yield performance under smallholder environments as is the case with drought tolerant maize in Malawi (Holden and Fisher, 2015). Greater involvement of Zambian farmers in the breeding process would likely improve the efficiency of hybrid maize seed choices and agronomic performance of existing hybrid varieties in Zambia. An institutional structure that involved a diverse array of public and private actors interacting with farmers and other stakeholders would likely have better outcomes than the current trickle down structure. More rigorous testing at the local level that involved testing varieties under a farmer field conditions with the farmer participation combined with more extensive outreach and extension would benefit farmers immensely.

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Seed choice paper figures and tables

Figure 1. Map of study area- shows location of respondents in SP, agroecozones, length of longest dryspells. Inset in a map of Zambia.

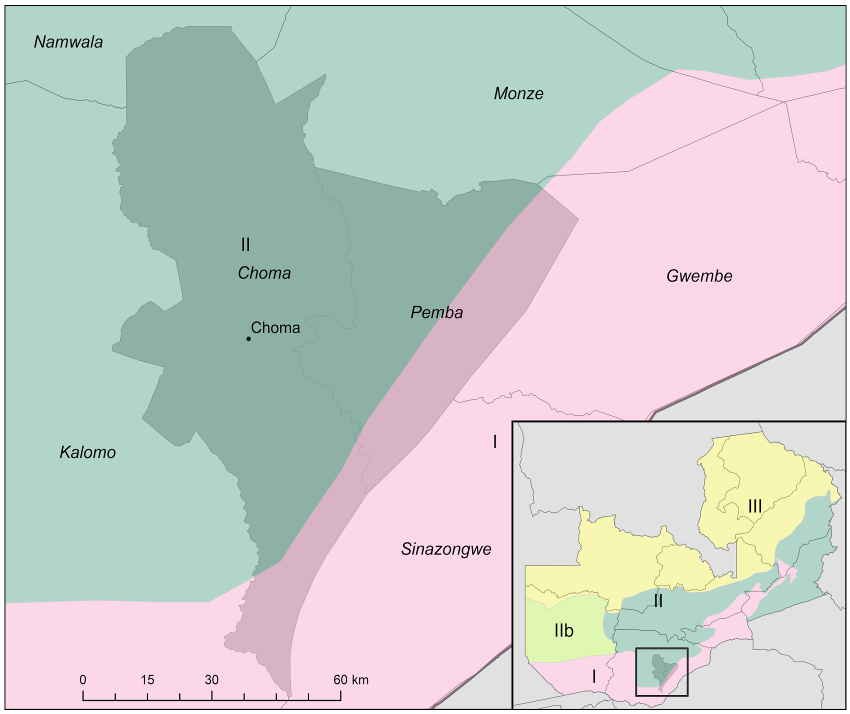
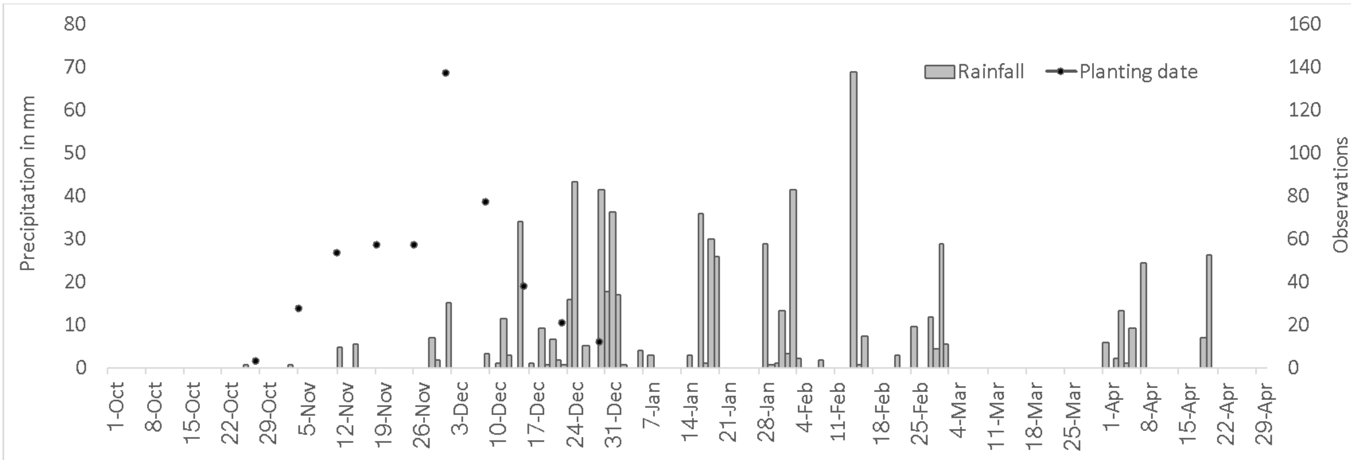
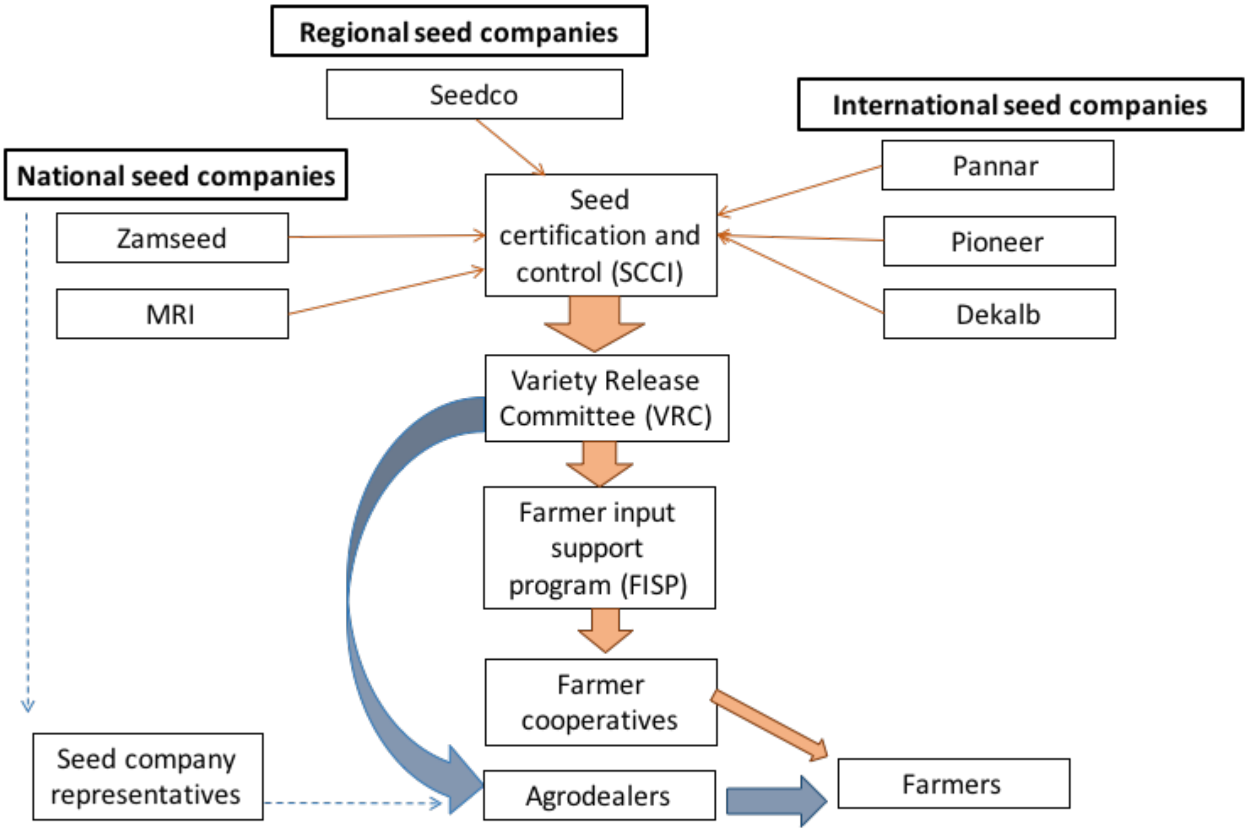


Figure 2. Precipitation and planting dates in Choma District, Zambia during the 2014-2015 season





*Note: the orange pathway illustrates the filtering of seed choice prior to the 2016 growing season and the blue pathway illustrates the filtering of seed choice after the introduction of the e-voucher system (rolled out in the 2015/6 season).

Table 1. Descriptive statistics of farmers (N=248)

Variable	Mean	Std. Dev	Min	Max
Gender (Male=1)	0.62	0.49	0	1
Age (years)	45.88	12.25	21	81
Household members	8.36	3.28	1	17
Children under 15	3.70	1.74	0	6
Young adults (15-30)	2.65	1.67	0	6
Male labor (men ages 30-65)	3.41	1.63	0	7
Female labor (women ages 30-65)	2.39	1.56	0	6
Household members over 65	0.26	0.57	0	3
Education level of respondent	3.52	1.17	2	7
Highest education level in HH	4.27	1.33	0	7

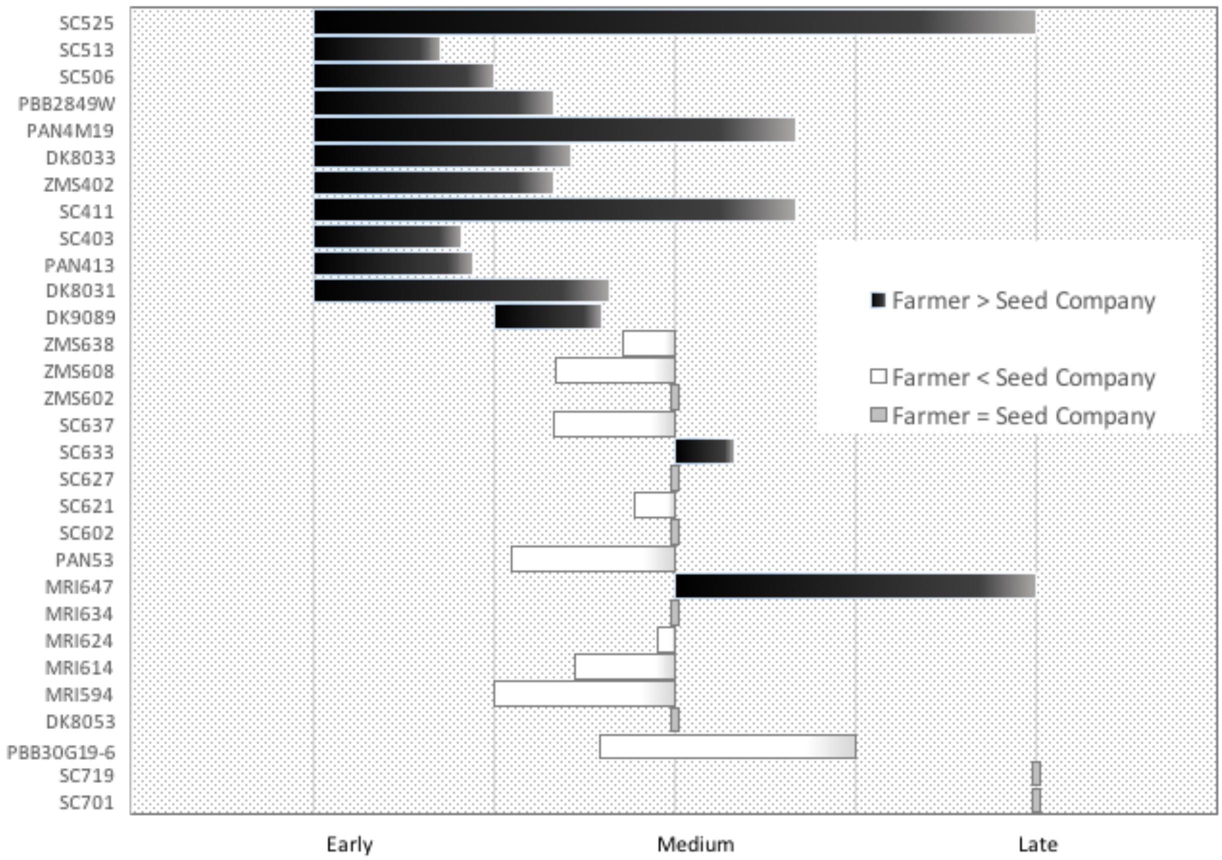
Table 2. Mean values of attributes associated with hybrid maize varieties farmers are familiar with

Variable	Mean	Std. Dev.
Good seed availability	0.68	0.47
High yielding	0.63	0.48
Good intercrop	0.57	0.50
Poundability	0.55	0.50
Tastes good	0.55	0.50
Good storage	0.53	0.50
Pest resistance	0.52	0.50
Drought resistance	0.51	0.50
Requires less seed	0.37	0.48
Low seed cost	0.33	0.47

Table 3. Seed varieties cultivated and relevant attributes

Variety	Obs	Classification	Days to maturity	Price (K/10 kg)	Price (K/25 kg)	Potential (mt/ha)
DK 8031	8	Very early	105	155	N/A	6.5
DK 8033	49	Early	110-115	157	N/A	10
DK 8053	1	Medium	120-130	157	N/A	10
DK 9089	1	Early/Medium	115-120	170	N/A	10
MRI 594	1	Medium	130	150	340	10
MRI 614	13	Medium	130	150	340	10
MRI 624	53	Medium	135	175	400	11
MRI 634	5	Medium	135	150	340	10
MRI 694	2	Medium				
PAN 413	44	Very early				
PAN 4M-19	1	Early				
PAN 53	55	Medium	135-140	160	400	9
PIO 30G19-6	64	Early	128	220	550	
PIO P2859W	2	Medium to Late	135-145	247	618	
SC 403	6	Very early	121-125	150	360	5
SC 411	2	Very early	121-125	150	360	8
SC 507	1	Early				
SC 513	58	Early	127-130	180	425	8
SC 525	3	Early	127-130	180	425	10
SC 608	2	Medium				
SC 621	3	Medium	130-136	190	445	9.5
SC 627	7	Medium	130-136	190	445	10
SC 637	5	Medium	130-136	235	540	13
SC 701	1	Late	140-148	345	760	13
SC 719	1	Late	140-148	320	750	14
ZMS 402	3	Very early				
ZMS 520	2	Early				
ZMS 606	50	Medium				
ZMS 608	6	Medium				
ZMS 638	1	Medium				
Total	**450**			**191.55**	**468.63**	**9.83**

Figure 4. Characterization of seed maturity by seed companies and farmers



*Note that each bar starts at seed company classification which is the darker end of the bar.

**Need to make separate figure for local varieties.

Figure 5. Farmer planting date by variety maturity classification

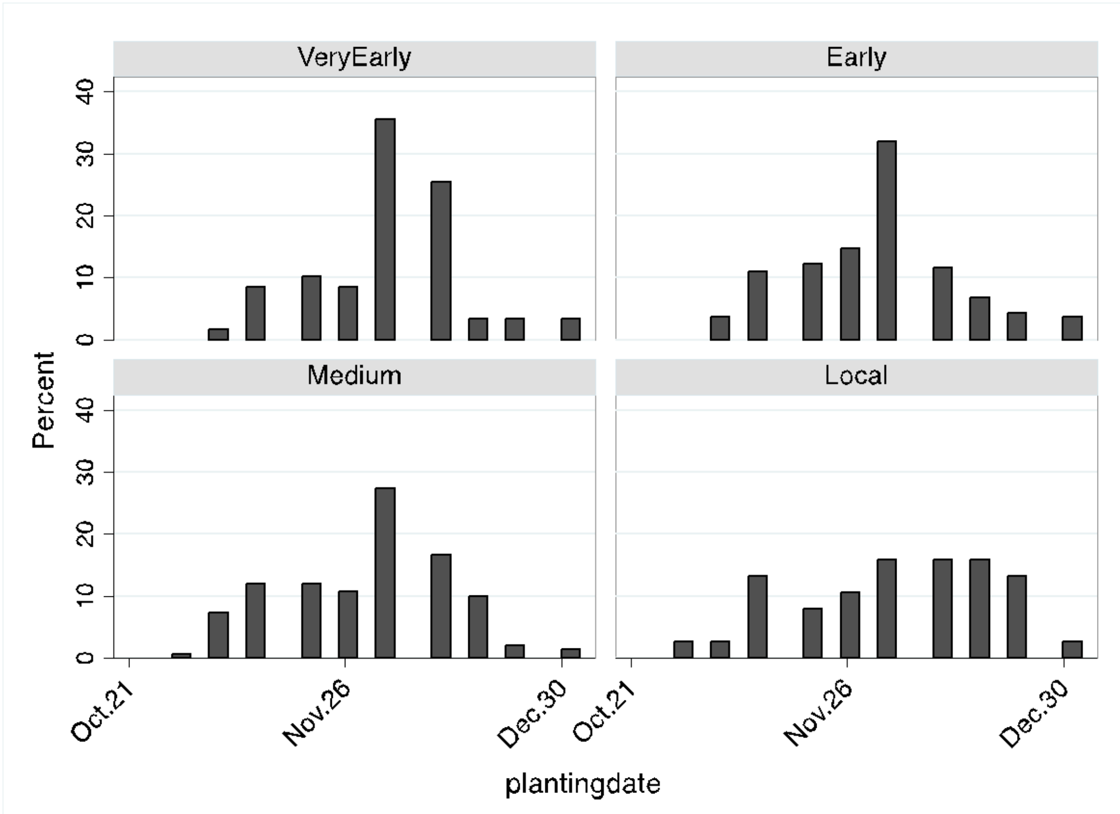


Figure 6. Mean yield by planting date for all seed varieties

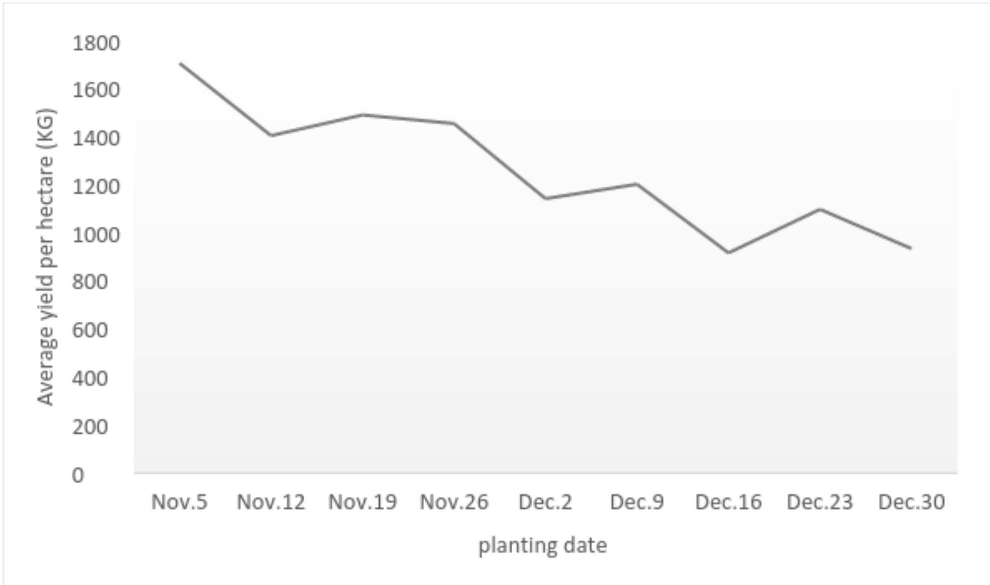


Figure 7. Mean yield per hectare across all farms by seed maturity class

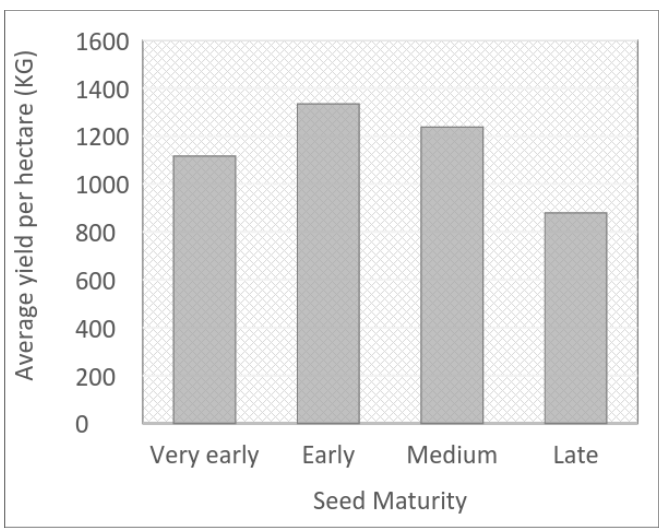


Figure 8. Perceived yield of 20 kg of local versus hybrid maize seed with different planting dates (under various conditions)

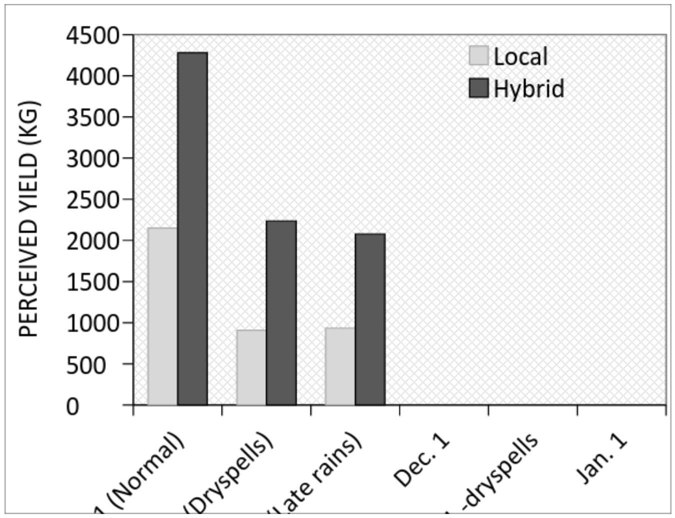
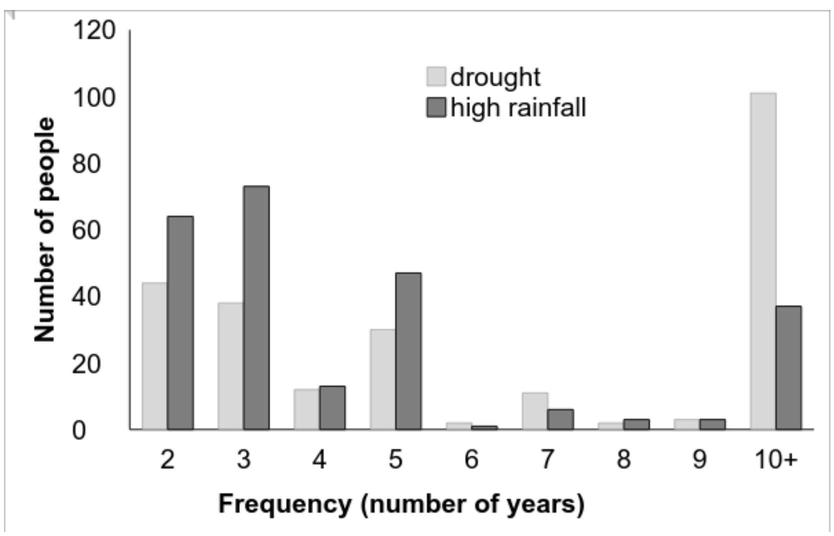


Figure 9. Farmers' expectations of a drought, high rainfall and normal year



	Very early		Early		Medium		Local	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z
Planting date	0.109	0.39	0.354***	0.01	-0.160	0.19	-0.387*	0.08
Rain optimism	-0.093	0.82	-0.812**	0.04	0.411	0.28	1.119	0.11
Drought probability	-0.319	0.78	-0.184	0.87	0.869	0.43	0.087	0.97
High rainfall probability	1.178	0.48	1.562	0.35	-0.526	0.74	0.369	0.90
Hybrid dryspell fraction	-0.035	0.60	-0.029	0.67	-0.040	0.54	-1.478***	0.01
Hybrid late planting fraction	0.007	0.79	0.004	0.75	-0.005	0.77	-0.002	0.92
Affectedfloods6yrs	0.844	0.17	0.182	0.79	-0.528	0.42	-0.037	0.98
Affecteddrought6yrs	0.765	0.12	-0.745	0.15	-0.263	0.62	-0.495	0.55
Affecteddryspells6yrs	0.237	0.68	1.237**	0.03	-0.806	0.14	1.330	0.14
Rain onset week 2013/4	-0.091	0.45	-0.359***	0.01	0.238**	0.05	0.039	0.85
Age	0.006	0.71	0.027*	0.09	-0.019	0.21	0.040	0.13
Asset Index	-0.218	0.15	-0.264*	0.07	0.099	0.47	-0.155	0.51
Highest education level	-0.264*	0.07	-0.414***	0.01	0.276*	0.06	-0.060	0.80
Total household labor	0.058	0.46	0.124	0.14	-0.072	0.32	-0.160	0.21
Off farm income	0.000	0.13	0.000**	0.05	0.000	0.39	0.000	0.76
Cooperative member	-0.641	0.47	0.674	0.43	0.935	0.33	-0.081	0.96
Received FISP last year	-0.469	0.55	-0.714	0.33	2.023**	0.02	-0.646	0.64
Distance to tarmac	0.000	0.94	-0.002	0.24	-0.001	0.47	-0.012*	0.06

Land titled	-0.701	0.27	0.563	0.34	0.185	0.72	-2.614**	0.04
Number of plantings	0.664***	0.00	1.420***	0.00	1.085***	0.00	1.715***	0.00
Choma Central	0.275	0.70	0.076	0.91	0.701	0.26	0.792	0.45
Batoka	0.040	0.95	0.351	0.60	-0.050	0.94	-0.332	0.73
Gamela	0.111	0.89	0.149	0.84	0.363	0.61	-1.324	0.29
Mbabala	0.058	0.93	0.073	0.91	-0.641	0.34	0.006	1.00
Popota	-0.083	0.91	1.560**	0.03	-0.394	0.51	-0.944	0.37
Sedumbwe	1.212	0.09*	0.813	0.27	0.667	0.39	0.000	
Singani	0.329	0.62	1.056	0.12	0.355	0.56	0.000	
Constant	-1.312	0.54	-2.553	0.24	-5.065**	0.02	-1.631	0.65
R2		0.14		0.24		0.25		0.33
N (%1)		0.23		0.69		0.51		0.12

*= statistical significance at the 10%, **=5%, and ***=1% level respectively.