Assessing access and adoption of common bean improved varieties in Zambia

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ACRONYMS

CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CSO	Central Statistical Office of Zambia
DNA	Deoxyribonucleic Acid
DoA	Department of Agriculture
FAO	Food and Agriculture Organization
GBS	Genotyping by Sequencing
GCP	Generation Challenge Program
GDP	Gross Domestic Product
ID	Identification
MSU	Michigan State University
NARS	National Agricultural Research System
NGO	Non-Government Organization
PABRA	Pan-Africa Bean Research Alliance
SABRN	Southern Africa Bean Research Network
SHA	Self Help Africa
UNDP	United Nations Development Programme
ZARI	Zambia Agriculture Research Institute
SPIA	Standing Panel on Impact Assessment
SIAC	Strengthening Impact Assessment in the CGIAR

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Abstract

Although common bean is a traditional crop for Zambia, it previously received modest support from the government. In 1982, research on bean improvement intensified, with investment from FAO/UNDP and CIAT. Consequently, there has been an increasing trend in the outputs of bean research in terms of the number of improved varieties developed and released in Zambia. Ten potentially high yielding improved bean varieties have been released. This study provides an analysis of the access, adoption and diffusion of improved bean varieties, the drivers of adoption, gender perspectives in bean production and marketing, and benefits derived from adopting the improved varieties (IVs). The analysis is based on a sample of 402 bean producing households selected from the Northern and Muchinga provinces. The study findings show that varieties released by the ZARI are known and used by farmers in the study communities but their extensive adoption remains highly constrained by seed accessibility problems. Because farmers in Zambia grow bean in variety mixtures, area allocated to seed of improved variety by early adopters continue to be small; consequently constraining the capacity of the farming communities to bulk sufficient seed and facilitate subsequent diffusion through farmer to farmer exchange of seed. Large scale investment in seed multiplication to reach many users after variety release will be needed to overcome seed accessibility constraints and quickly achieve wide diffusion. The analysis also reveal a substitution effect between varietal and non-varietal soil fertility management options such as chemical fertilizers, offering support to the breeding for resistance and adaptability to physical conditions, as a pro-poor strategy to sustain bean production. Given that the poor have limited access to chemical fertilizers, efforts to ensure that they gain access to improved bean varieties will contribute significantly to the country nutrition and poverty reduction objectives. The study findings also support the conclusion that additional interventions are need to address gender biases in bean production of Zambia which favor men against women, with pronounced variations across provinces.

Assessing access and adoption of improved bean varieties in Zambia

1.0 Introduction

1.1 Background information

Agriculture remains the single most important source of livelihood for the majority of smallholder farmers in Zambia, providing sources of livelihoods for over 50% of the country's population. The agricultural sector contributes between 13-20% to the country's Gross Domestic Product (GDP) and about 67% to employment. Among the food legumes grown in Zambia, common bean ranks second (after groundnuts) in terms of its economic importance. It constitutes about 32.1% of the total area under food legume crops (roughly 85,469 ha) cultivated annually (CSO, 2012), is an important source of proteins and micronutrients (especially Iron (Fe) and Zinc (Zn)) for children, and is increasingly becoming an important cash crop, shifting from a women-dominated crop to a joint enterprise where both men and women are producers.

Until the beginning of the 1990s, agricultural policies in Zambia were biased towards maize and not very favorable for food legume crops, such as beans. Large-scale marketing support coupled with extensive fertilizer and input subsidies induced farmers to devote ever-larger tracts of land to maize production (Wood *et al.*, 1985; IESR, 1999; Zulu *et al.*, 2000) at the expense of crop diversification. In 1991, the decades of large-scale maize subsidies came to an abrupt end, with a change in government. In response, farmers diversified out of maize production and reduced fertilizer use by over two-thirds, as availability diminished and input prices escalated (Haggblade & Tembo, 2003). The agricultural policies were adjusted and refocused to lay emphasis on crop diversification and to include low-input crops like food legumes, which have proven to be more appropriate for resource-poor small scale farmers.

Despite a favorable policy environment, the growth in bean production has been modest as indicated in the Zambia Agriculture Sector Profile report of 2011 (CSO, 2012). Zambia still remains a net importer of bean grain compared to its neighbors, such as Tanzania and Mozambique, who are net bean exporters. The constraints affecting bean production in Zambia are well documented (CIAT, 1989) and broadly include poor agronomic practices, soil infertility, lack of improved cultivars, moisture stress, weed competition and stress caused by weed competition as well as pests and diseases. To date, the Ministry of Agriculture and Livestock, in collaboration with non-governmental and international organizations (e.g., International Center for Tropical Agriculture-CIAT) and the United Nations organizations (e.g., Food and Agriculture Organization-FAO, United Nations Development Programme-UNDP), have devoted efforts to solve these problems with the objective of ensuring household food security and increased incomes among smallholder farmers. One such effort includes working on the development and promotion of improved cultivars with high yield potential so that farmers can increase output and agricultural income.

The National Agriculture Research Systems (NARS) in Zambia have released ten improved bean varieties to date, seven of them are bush varieties, two are semi-climbers and one is of climbing type. These varieties have high yield potential (1-2 tons/ha) and bush-type varieties only take two to three months to mature. The earliness of bush varieties has enabled many bean growers in the high-rainfall northern region of Zambia to grow at least two bean crops in a single season. In terms of management, most of the varieties developed so far are adapted to relatively low soil fertility conditions. However, additional breeding research is still needed in terms of nutritional content as well as pest and disease resistance. The improved varieties (IVs) have been disseminated through a number of channels that include on-farm variety demonstration plots, bean utilization demonstrations, off-season production, and the production and distribution of brochures containing bean production and utilization information.

1.2 Historical perspectives of bean technology development and dissemination

The common bean (*Phaseolus vulgaris L.*) is an ancient new-world domesticated crop. Literature indicates that beans spread widely in post–Columbian times and came to Africa from Brazil with the slave trade (CIAT, 1989). In Zambia, the production of beans could be traced back to before the colonial era. The breeding research on beans in Zambia started way back in the 1950s at the Lunzuwa Research Station of the Mbala district in the Northern Province. Prior to this, most smallholder farmers relied on local seeds characterized by low quality, susceptibility to pests and diseases, poor yields, low germination rates and lack of uniformity. The main objective of bean breeding was to develop varieties tolerant and resistant to pests and diseases so as to increase farmers' yields (MAFF, 1993). As a result, a range of varieties were released between 1966 and 1970, including Misamfu Speckled Sugar, Misamfu Stringless and Mexican 142 (Table 1). These successes were however not followed and efforts to come up with new varieties proved fruitless. For instance, two varieties (BAT85 and BAT331) released between 1977 and 1983 were only short-lived and have since disappeared. Later in the mid-1980s, a high yielding variety called Carioca was released but received limited acceptance due to its poor palatability, small size and poor cooking quality.

Research on bean improvement intensified in 1982, by a grain legumes research team based in Chipata district for the Eastern Province, with financial assistance from FAO/UNDP and CIAT. Diagnostic studies (particularly in the Northern Province) were done to better understand farmer preferred variety traits and production constraints. These studies conducted by ZARI confirmed high susceptibility of local landraces to pests and diseases, low soil fertility and soil acidity.

Over the years, both the government and the donor community, notably the UNDP, FAO, World Bank and CIAT through the Southern Africa Bean Research Network (SABRN) have invested substantial resources to develop improved varieties. Table 1 summarizes the varieties that have been developed, tested and released for use by farmers since 1970. Besides development of bean varieties, the National Agricultural Research System under the Ministry of Agriculture and Cooperatives has been collaborating with other stakeholders: Non-Government Organizations (NGOs), seed companies and donors in the dissemination of improved technologies.. Nevertheless, the country's dissemination programme has been fragmented with little cohesion among partners, which has limited the impact of these technologies.

The Zambia Agricultural Research Institute (ZARI) conducts on-farm research trials and demonstration plots to evaluate and select suitable varieties with farmers, which also serve to inform farmers of the new varieties. These activities are linked to the Department of Agriculture that further extends the information to more farmers. At the time of this study, the Department of Agriculture (DoA) in collaboration with ZARI, SABRN, Plan International, Self Help Africa (SHA) and World Vision International was conducting dissemination of bean-based technology in several communities particularly in Kasama and Mbala districts in Northern and Mpika district in Muchinga Provinces.

Table.1. Bean varieties developed and/or screened from landraces and released in Zambia between 1970 –2012.

Variety	**CGIAR code/Source**	**Year of release**	**Title holder/Agent**
Mexican 142	Not available	Not available	Zambia Seed Company Ltd
Boroti	Not available	1970	Zambia Seed Company Ltd
Misamfu Stringless	Not available	1973	Zambia Seed Company Ltd
Misamfu Speckled Sugar	Not available	1979	Zambia Seed Company Ltd
Bat 331	Not available	1984	Zambia Seed Company Ltd
Carioca	Not available	1984	Zambia Seed Company Ltd
Contender	Not available	1984	Zambia Seed Company Ltd
Glamis	Not available	1984	Zambia Seed Company Ltd
NEP 2	Not available	1984	Zambia Seed Company Ltd
Top Crop	Not available	1984	Zambia Seed Company Ltd
Chambeshi	A 197, Rwanda	1998	Zambia Seed Company Ltd/ZARI
Lukupa	PEF 14, CIAT	1999	Zambia Seed Company Ltd/ZARI
Lyambai	CAL 143, CIAT	1999	Zambia Seed Company Ltd/ZARI
Bounty	Not available	2004	SeedCo International (Z) Ltd
Kalungu	SPS2 4P 24	2004	Zambia Agricultural Research Institute (ZARI)
PAN 148	Not available	2006	Pannar Seeds (Z) Ltd
Cardinal	Not available	2007	Progeny Seeds
Kabale	KID 31	2007	Zambia Agricultural Research Institute (ZARI)
Kabulangeti*	Local Markets	2007	Zambia Agricultural Research Institute (ZARI)
Kapisha	C30-P20	2007	Zambia Agricultural Research Institute (ZARI)
Speckled Ice	Not available	2007	Progeny Seeds
PAN 116	Not available	2008	Pannar Seeds (Z) Ltd
PAN 128	Not available	2008	Pannar Seeds (Z) Ltd
PAN 185	Not available	2009	Pannar Seeds (Z) Ltd
Lwangeni	OPS-KW1	2009	Zambia Agricultural Research Institute (ZARI)
PAN 123	Not available	2010	Pannar Seeds (Z) Ltd
Kalambo	VTTT 923/10-3	2011	Zambia Agricultural Research Institute (ZARI)
Sadzu (Climber type)	MAC 23	2011	Zambia Agricultural Research Institute (ZARI)
Mbereshi	NUA 45	2012	Zambia Agricultural Research Institute (ZARI)
Local screened varieties			
Mbala Local*	Mbala farmer	1985	ZARI
Chipata Local*	Chipata farmer	1986	ZARI
ZPv 292 *	Eastern province	1986	ZARI
Solwezi Rose*	Solwezi - farmer	1994	ZARI
Pembela*	Kasama - farmer	1996	ZAR

Sources: Zambia Seed Control and Certification Institute Register, 2013; ***** Means that these varieties were developed from screening local varieties.

1.3 Purpose of the study

The main purpose of this study was to provide estimates of the rates of adoption of improved bean varieties in northern Zambia, particularly, in the Northern and Muchinga provinces. The increasing trend in the outputs of bean research in terms of the number of improved varieties developed and released in Zambia is clear. However, less clear isknowing how widely these varieties are adopted in this region. This study aims to bridge this information gap and thus provides an analysis of the access, adoption and diffusion of improved varieties, the drivers of adoption, gender perspectives in bean production and marketing, and benefits derived from adopting the improved varieties (IVs).

2.0 Research methods and materials

This section provides an overview of the data collection process and analysis used in this study. Specifically, it outlines key issues pertaining to the research strategy, study sites (i.e., target population) and sampling, study design, data collection methods, and analysis strategies.

2.1 Research strategy[1]

Two types of data collection strategies were used. : 1) a desk review of information pertaining to bean production and 2) a household survey of smallholder bean producers. Literature review was conducted to have a better understanding of the development and dissemination aspects of improved bean varieties in Zambia, policy factors that have contributed to the diffusion of improved bean technologies among smallholder farmers and also to learn about successes, failures and research gaps regarding bean technology promotion. This review helped to get better insights pertaining to the trends in improved bean technology promotion, policy and program implementation that may have influenced the diffusion of improved bean varieties in both marginal and high-potential bean producing areas of northern Zambia. Further, while the household survey provided rich data about farmers' production and marketing decisions, as well as the importance of the bean crop in the household diet and as a source of income, this survey

[1] The research strategies used in this study are derived from the research book, "*Verschuren, P. and H. Doorewaard (1999) Designing a Research Project. Utrecht, Lemma".*

was also accompanied with a village-level questionnaire that allowed us to understand macro factors affecting sampled bean producers.

2.2 Study sites and sampling

2.2.1 Study area

The study was conducted in Muchinga and Northern provinces of Zambia. These provinces were purposively selected because of their high importance in bean production, accounting for about 70% of the area under beans in Zambia (Table 2). The crop production is relatively higher in the northern and Eastern Provinces of Zambia because the environmental conditions are favorable. Accordingly, most of the dissemination efforts have concentrated in the Northern Province, further justifying our focus on these regions for this study.

In the Northern Province bean is an important cash crop for small farmers. Cultivation is mainly under a practice locally termed as "Fundikila System", which involves the formation of mounds of grass (predominantly *Hyparrhenia filipendula* and *Pennisetum purpureum*) covered by earth, on a previously fallowed site towards the end of the rainy season to minimize on input expenditure. Compared to other countries in the region, particularly Kenya, Uganda and Tanzania, Zambia is at a competitive disadvantage due to the relatively high cost of production (Odhiambo *et al.*, 1996). The cost of labour is very high and agriculture is less mechanized in the northern region of the country, thereby increasing the cost of production compared to other regions where mechanization is common.

The Northern and Muchinga provinces fall in the high-rainfall agro-ecological region III of Zambia. The Region III has an average precipitation of 1,000 mm per annum, a growing season of 120-180 days long, and an average temperature of 16-25^{o}C. The major crop production constraints include soil acidity (making only 53% of the land suitable for cultivation), poor market access, large areas of wetlands, dambos, rivers and lakes, and lack of irrigation during production.

Table 2. Total area (ha) planted with beans in the 2011/12 producing season in the study sites, Zambia.

Province/Selected *Districts*	**Area (ha) under beans**	**Share (%) of total national bean area**
Muchinga	**11,074**	**12.5**
Mpika	2,325	2.6
Chinsali	2,895	3.3
Nakonde	3,455	3.9
Other districts	2,399	2.7
Northern	**50,984**	**57.5**
Mbala	25,550	28.8
Mpulungu	6,386	7.2
Kasama	4,978	5.6
Mporokoso	6,827	7.7
Other districts	7,243	8.2
Zambia	**88,673**	**100**

Source: CSO, 2011/12 Crop Forecast Survey.

2.2.2 Sampling

A total of seven districts were purposively selected (because of the importance of the bean crop) from the two provinces: four districts (Kasama, Mbala, Mporokoso, Mpulungu) in the Northern Province and three (Chinsali, Mpika, Nakonde) in the Muchinga Province, which represents 86% and 78% of the total area planted in each province, respectively (Table 2). Further, the area planted to beans in the seven districts represents 59% of the total bean area of Zambia (Table 2).

After the districts were selected, a two-stage cluster sample selection method was used. In the first stage, villages were randomly selected from each district according to the proportion of villages within the selected districts in each province. In the second stage, households were systematically selected within each village. To be able to implement this two-stage sampling, the following steps were followed. First, the total number of villages to include in the study was determined mostly based on the available budget, which allowed sampling about 402 households. Further, it was decided that six households would be sampled per village. This information was used to obtain a total of 67 villages (402/6=67) to include in the study. There were a total of 13 districts in the two provinces, eight and five districts in the Northern and Muchinga provinces, respectively. The proportion of districts (i.e., 8/13 and 5/13) was used to determine how many villages would be selected from each province (within the seven selected districts). Thus, 41 and 26 villages were selected in the Northern and Muchinga provinces, respectively (Table 3).

Table 3. Villages and farmers sampled, by province and district in Zambia, 2013.

Province/*District*	Total villages	# of villages selected	Intended sample	# of farmers interviewed
Muchinga	1,146	**26**	**156**	**161**
Chinsali	287	7	42	42
Mpika	674	15	90	95
Nakonde	185	4	24	24
Northern	798	**41**	**246**	**241**
Mbala	245	12	72	72
Mpulungu	288	15	90	86
Kasama	12	1	6	6
Mporokoso	253	13	78	77
Muchinga + Northern	1,944	67	402	402

In total, 67 villages were sampled for the study. The villages were randomly selected proportionally to the number of villages in each district within each province (i.e., this step was repeated for each province).[2] This implies that different numbers of villages were included in the sample for each district, as indicated in Table 3. Once the villages were identified, six households were randomly selected within each village for the survey. Although it was expected that from the 402 sampled households, 246 would come from the Northern and 156 from the Muchinga provinces, in reality, 241 households were sampled in the Northern and 161 in the Muchinga provinces; Table 3). This was because one extra village from the Mpika district was sampled and a few households from several villages within the Mpulungu district could not be sampled.

To select the households, a systematic random sampling procedure was followed. The enumerators requested a village register from the local headman or in some cases, the village secretary. This register served as the sampling frame and each household in this list was numbered sequentially. The total number of households was divided by six (the number of sampled households per village) to get a fixed interval that was used for household selection.

[2] Ideally, the number of villages and the criteria for selecting the villages should have been based on the relative importance of the bean area planted. However, this information (i.e., bean area) was not available at the village level.

While the first household was selected at random from the list, the remaining five households were chosen at fixed intervals after the first household was selected.

2.3 Survey materials, data collection, variety identification

To collect the necessary data, three questionnaires were developed: a household level questionnaire and a village level questionnaire. The household and village level questionnaires were administered via face-to-face interviews. The 19-page household level questionnaire (available from the authors upon request) was used to elicit information on the household composition, socioeconomic characteristics, land holdings, bean production and its use, sales and use of revenues, decision-making, current and past use of bean varieties, varietal preferences and demand for seed, social capital and networking, access to services, importance of beans and other crops in the household economy, and dietary diversity.

The six-page village level questionnaire (available from the authors upon request) contained questions to collect general information of the people interviewed, general information about the village, market access, services available, and major shocks/events experienced in the village in the last five years. The third instrument (also available upon request) was prepared to record key information about the bean vendors and market grain samples collected from two local markets in Kasama.

The survey was implemented between August 1st and September 10th of 2013 and the information collected refers to the 2012-2013 agricultural season (December 2012-April 2013). A total of 20 enumerators were trained at the Zambia College of Agriculture located in Mpika, Muchinga province, on July 22-25, 2013. Collaborators from ZARI, CIAT and MSU participated in this training. The enumerators learned how to use the instruments for household- and village-level data collection and also how to collect seed samples (including proper labeling) that was later identified by experts in a workshop convened by the ZARI. Each survey team included a supervisor and six enumerators. Farmers' participation in the survey was voluntary and they were fully informed on the survey objectives and how they were selected to participate in the survey.

Each enumerator received a set of seed samples representing (ten) different varieties that was presented to the farmer to facilitate in variety identification. Each small plastic bag containing these seeds had a code and only the supervisors knew which code belonged to which variety. Additionally, the enumerators received a camera which was used to take photos of seeds and enough manila envelopes and stick labels to collect seed samples from farmers. The photos and seed sampled collected from farmers were later used in variety identification by a panel of six bean experts who were familiar with the varieties grown in the study districts and who worked for the extension service of the Ministry of Agriculture. These were invited to ZARI's Misamfu Research Station in Kasama to participate in the identification of varieties using photos and seed samples. Regarding their education level, four of the experts had a Diploma (3 years post-secondary/tertiary education) and two had a Certificate (2 years post-secondary/tertiary education).

Further, three of the six experts were female. Collaborators from ZARI and MSU participated in this elicitation process, which was done in March 2014. If the experts could not name a variety, "no name" was recorded as their answer. This happened in few cases. The computer used to show the pictures was different from the computer used to record the answers, which speeded up the process. In another round, the supervisors passed one seed envelope to the experts, who observed the seed sample, and after some exchange of opinions, reached a consensus about the name of the variety. If they could not identify a variety by name, "no name" was recorded as their answer (which also happened in few cases). At this moment, when a variety was identified as a "mixture" (which is common in Zambia), each of the varieties within this mixture were evaluated separately (i.e., each was given a name.

2.4 Overview of the data analysis strategy

Most of the results presented in this report are based on descriptive analysis using t-test statistic, ANOVA and Chi-Square statistics. The descriptive analysis is anchored on the livelihoods framework. As defined by Ellis (2000), a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. O'Donnell (2004) has argued recently that the livelihood framework can provide a clear basis for understanding how technologies such as crop hybrids can impact various aspects of livelihoods in different ways at the household level. Econometric analysis was also used to provide insights into factors that influence the decision on whether or not to adopt improved varieties.

2.5. Econometric framework

A two-step sequential econometric estimation approach was applied to study the factors that influence the adoption of improved bean varieties in northern Zambia. In first step, the analysis focuses on factors that influence the likelihood that farmer *i* becomes aware of an improved bean variety modeled as binary probit. Conditional on awareness, we distinguish farmers in terms of their adoption decisions on whether or not to allocate plot j to the improved bean variety(s).

Bean producers in Zambia reside in remote rural areas connected to urban centers by poorly developed road networks. Hence, the cost of transportation and lack of access to markets constrain some farmers from access to full information and production inputs like seed of the new crop varieties (Shiferaw et al., 2008). In such conditions, decision makers are assumed to choose varieties that maximize their expected utility given their knowledge on available stock of varieties, household characteristics, conditions in the physical production environment and market conditions (Sigh et al., 1986; Sadoulet and deJanvry, 1995).

Let $U^{L}{}_{Ij}$ be the utility farmer i derives from a local variety cultivated in plot j and $U^{V}{}_{ij}$ the utility from cultivating improved variety in plot *j*. The farmer is assumed to compare the expected utility he/she derives from the improved variety with the expected utility from a local variety and decides to adopt improved variety if the net benefit is positive i.e. $Y_{ij}^{*} = U^{V}{}_{ij} - U^{L}{}_{ij} > 0$. The net benefit $Y^{*}{}_{ij}$ from an improved variety is latent unobserved variable determined by household, plot and village level factors (X) as well as unobserved characteristics (μ_{ij}) expressed as:

$$Y^{*}{}_{ij} = \beta X + \mu_{ij} \qquad (1)$$

Where *Beta (* β) is a vector of coefficients to be estimated. The latent unobservable variable $Y^{*}{}_{ij}$; is observable for plots j of household i whose decision to cultivate improved bean variety is positive and remains unobserved represented as dummy indicator $Y_{ij} = 0$ for non-adoption decision outcomes.

$$\begin{aligned} Y &= 1 \quad if \quad Y_{ij}^{*} > 0 \\ Y &= 0 \quad if \quad Y^{*}{}_{kj} \leq 0 \end{aligned} \qquad (2)$$

The zero responses can result from some farmers who are aware of the varieties but are unable to adopt because they lack access to seed of improved varieties as was the case in Shiferaw et al.

(2008) who demonstrated that poor access to seed constrains adoption of improved legume varieties in Tanzania. The zero response can also be unobserved responses associated with lack of information about the availability of improved bean varieties and reflect sample selection problem due to study design. Yet for other farmers, the zeros might reflect a zero seed demand for the improved varieties by household i if outperformed by local ones as perceived by the decision maker. In case of the first explanations, analysis of equation 2 with a binary probit without correcting for selection bias can result in biased and inconsistent estimates. This will happen if individuals who belong to the informed group (treatment group) systematically differ from those in the uninformed group (the unaware of improved bean varieties) in terms of their observed and unobserved characteristics.

Consistent estimates can be obtained by estimating equation 2 with a selection, that allows for different mechanisms to the outcome of decision to cultivate the improved variety or not and information acquisition. While it is easy to collect data on adopters, specific data on those who do not adopt is rarely detailed enough. Through the survey, each farmer was asked to list all the improved varieties known to him/her. From these responses, we derive a variable that captures the household awareness of the improved varieties and the number of varieties known to the households. We use a dummy of awareness as an indicator of access to information about the stock of the improved varieties to identify factors that constrain and facilitate access to information, a prerequisite to adoption were investigated. Based on this variable, bean producers in rural Zambia are assumed to have unequal access to information. Some have obtained information on the availability of the improved varieties and others lack information on improved varieties.

If A^* denotes unobservable variable describing the possibility that individual i accesses information on improved bean varieties, we can express the selection equation as a function of observable (Z) factors on demand and supply sides of technology access and unobservable factors (ε): Then the probit model with a selection can be expressed as follows:

$$A_i^* = \lambda Z + \varepsilon_i \tag{3}$$

$$\begin{aligned} Y_{ij} &= 1 \quad if \quad \lambda Z + \varepsilon_i > 0 \quad \& \; \beta X + \mu_{ij} > 0 \\ Y_{ij} &= 0 \quad if \quad \lambda Z + \varepsilon_i > 0 \quad \& \; \beta X + \mu_{ij} \le 0 \\ & \qquad\; if \quad \lambda Z + \varepsilon_i \le 0 \; \& \; \beta X + \mu_{ij} \le 0 \end{aligned} \tag{4}$$

Where Vector ε_i and vector μ_{ij} consist of error terms that are assumed to have bivariate normal distribution with a covariance matrix given as:

$$\begin{bmatrix} 1 & \delta\rho \\ \delta\rho & \delta^2 \end{bmatrix} \quad (5)$$

Vector Z and X are sets of explanatory variables that enter into model 1 (our selection model) and model 2 (the outcome equation). The relevant explanatory variables in the empirical models are selected based on the previous empirical adoption studies, theoretical consideration in this section as well as our knowledge of the empirical context of the study area. The hypothesized factors that influence adoption of improved bean varieties can be categorized as: individual and household, farm characteristics, market conditions and villages context.

3.0 Descriptive results

3.1 Importance of common bean and cropping system

3.1.1 Bean production, intercrops and harvesting

In the study area, a household owns on average 9.64 ha of land, 2.35ha of which are cropped. A multiple of crops including common bean are cultivated in the cropping season that occurs between March and July. Nearly every household cultivated bean in the study season (2012/2013), but maize is the most important crop in terms of area planted for 64.3 percent of the households, followed by *cassava* (15 percent), and common *bean* (12 percent). Common bean is also ranked the second most important by majority (46.6 percent) of the households followed by m*aize* (19.3 percent). Per agricultural season, a typical household allocates 0.46 ha of land to bean production, which constitutes about 31 percent of the total land cultivated in the season 2012/2013 (Table 4). Common bean, mainly of bush type is frequently grown in association with other crops, maize being the dominant intercrop (51.2 percent), followed by cassava (40 percent).

Important regional patterns exist (Table 4). In terms of area, common bean is more important in Northern Province—cultivated on 0.74Ha (about 31 percent of cropped area) compared to 0.35ha (27 percent of total cropped area) in Muchinga (Table 4).

Table 4: Common beans production (Ha), intercropping, harvesting and utilizations

	Muchinga Province		Northern Province		All sample	
Characteristic	Mean	SD	Mean	SD	Mean	SD
Landholding (Ha) (N=384)	9.6	20.7	9.7	22.4	9.6	21.7
cropped land (N=393)	2.3	2.5	2.4	2.6	2.4	2.6
% cropped land owned	97.8	14.0	97.8	14.8	97.8	14.4
Number of fragmented bean plots	1.3	0.6	1.4**	0.7	1.4	0.7
Bean plot size (ha)	0.3	0.4	0.6***	0.9	0.5	0.8
Bean area (ha) per household	0.4	0.4	0.7***	1.4	0.7	0.1
Number of plots sampled	206		336		542	
Total quantity harvested dry	107.5	134.5	274.5	414.4	209.0	343.5
Quantity of dry harvest sold	56.9	108.3	183.0	360.7	133.2	295.0
Quantity of dry harvest kept for seed	19.4	22.4	39.3	45.7	31.4	39.4
Quantity of dry harvest used for food	21.9	23.1	29.7	46.0	26.6	38.7
		Percentage				
HH that grew beans in 2012/2013	99.5		99.8		99.7	
Bean plots intercropped	50.6***		35.0		36.8	
Popular bean intercrops						
• Maize	79.6		45.0		51.2	
• Sorghum			2.5		2.1	
• Cassava	5.4		47.5		39.9	
• Cowpea	2.1		0.0		0.4	
• Sunflower	2.1		2.0		2.0	
• Sweet potato	9.3		1.1		2.5	
• Others	1.6		2.0		1.9	
Staggered harvesting (% plots)	67.0		69.6		68.6	
• All green pods sold	2.88		2.99		2.95	
• All green pod consumed	84.89		94.44		90.88	
• Green pods sold and consumed	12.23		2.56		6.17	

Source: Own survey

Farmers in the Northern Province also cultivate more bean plots, about 1.42 per household of 0.55 hectares average size, compared to farmers in Muchinga where bean plots are fewer and of smaller size (about 0.34ha). However, bean plots are more frequently intercropped in Muchinga, where slightly more than a half of the bean plots are mixed, compared to only 37 percent in the Northern Province (Table 4). Maize is the most important bean intercrop in Muchinga accounting for 80 percent of cases while beans are commonly intercropped with maize (45 percent of mixed plots) and cassava (47 percent of mixed plots) in Northern Province.

Bean harvesting is mainly staggered (reported on about 69 percent of bean plots) and begins when the grain is still at green stage. By the time the grain matures to dry stage, about 25 percent or more of the bean yield in a plot is already harvested and mainly used for home consumption (91 percent), but a few can be sold outside the farm (Table 4). However, for most of the plots (52.4 percent), pods harvested greens account for 25% or less of bean produced (Appendix A1.3). When bean is fully dry, it is all uprooted and put to different uses. On average, households in the study area harvest a total of 209.0 kg of dry bean grain, about 133.2 kg of which is sold, 31.4kg kept as seed for planting next season and 26.7 kg used as food (Table 4).

3.1.2: Common bean marketing and gender perspectives

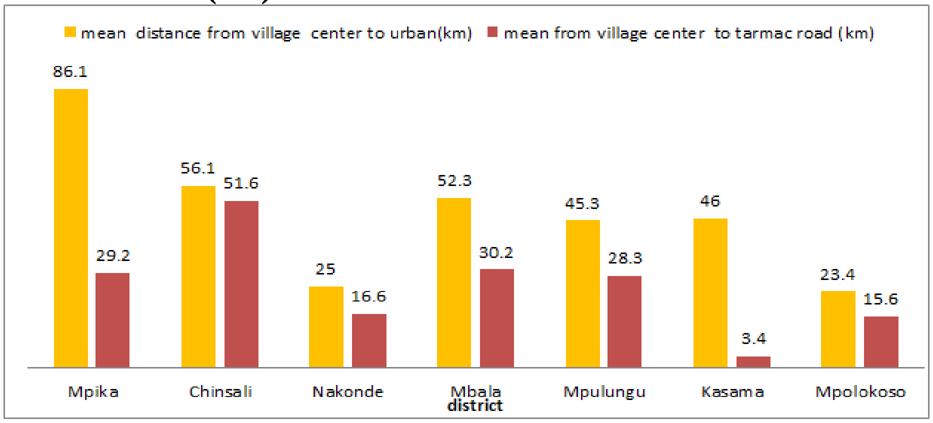
A big proportion of households 973.6 percent) sell part of the bean after harvest but this percentage is significantly lower (63.13 percent) in Muchinga (Table 5). Much of the bean sales occur in about one transaction of about 96 kg size (Table 5).

Table 5: Dry bean grain marketing

Marketing of beans	Muchinga Province		Northern Province		All sample	
	Mean	SD	Mean	SD	Mean	SD
Number of transactions	0.8	1.1	1.1	0.9	1.0	1.0
quantity sold per transaction	42.5	75.0	124.9	224.2	96.4	190.5
Producer price (Kwacha/kg)	4.5**	4.2	3.6**	1.5	3.9	2.8
	Percentage of households					
Sell dry bean grain	63.13		80.41**		73.58	
Share of dry harvest marketed	35.87		53.02**		46.25	
Point of first sale						
• Farm gate/home	49.62		73.91		65.54	
• Village market	21.8		10.67		14.51	
• Main/district market	28.57		15.42		19.95	

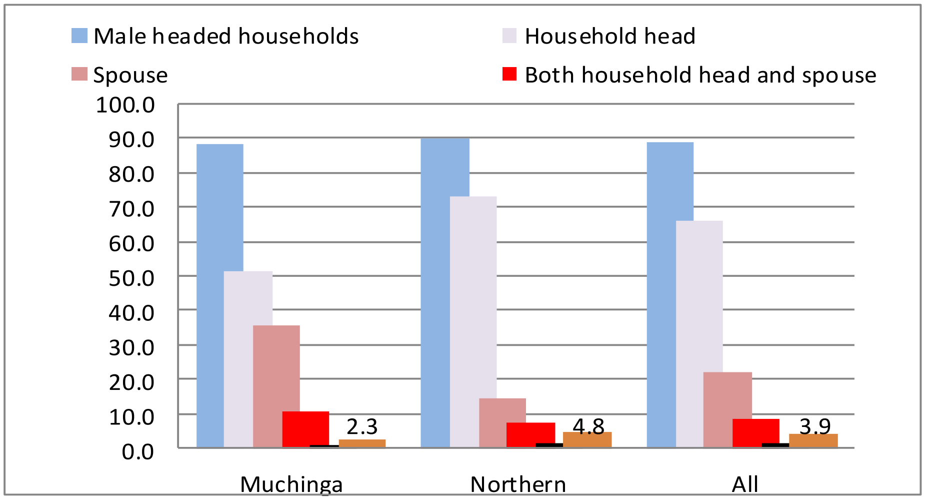
Producers receive average price of about K3.9 per kg for dry bean grain which varies between from K.1 to K.40 per kg depending on the time and location of sale. Bean grain producer price is higher in Muchinga (average of K4.4/kg) than in Northern Province (average of K3.6/kg) and in the months of July and August that follow immediately after harvest. Farm gate is the most common point of first sale accounting for 65.5 percent of the transactions since most of the households have no market in the villages of their residences. Only 14.5 percent of the households reported having a market within their village. Although farmers are located in remote areas far from the urban or tarmac road (Fig 1), several categories of buyers including urban based traders participate in farm gate markets. At farm gate, rural brokers/middlemen are the most important buyers accounting for 52 percent of the transactions, followed by consumers (31. 4 percent) and then urban wholesalers 13.9 percent (Appendix A1.2).

Figure 1: Distance (km) from the tarmac road and district town



Most of the transactions are conducted by the household heads, majority of whom are males, while spouses who are mainly females make about 20 percent of the transactions but slightly less in the northern province (about 15 percent) than in Muchinga (about 35 percent) (Fig 2). However, average price received by the producer does not depend on the type of the household member managing the transaction.

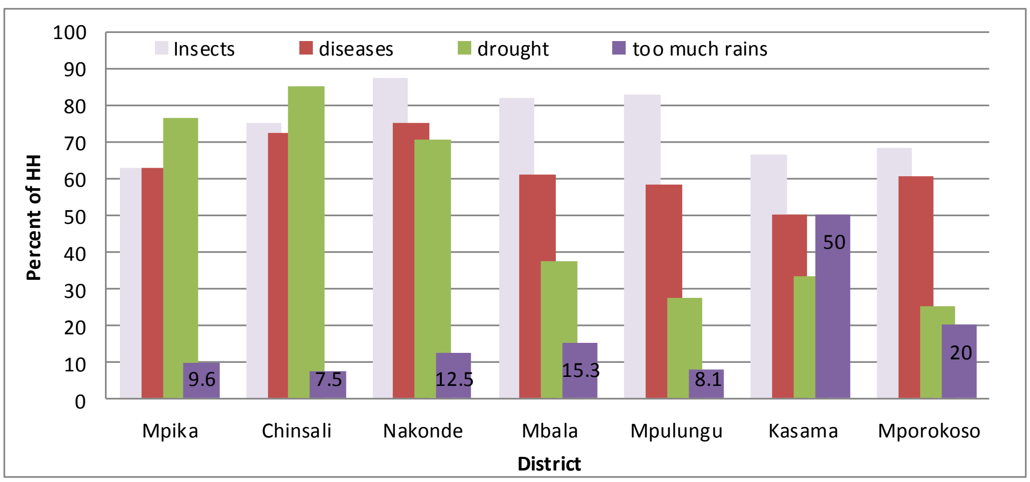
Figure 2. Type of household member involved in bean transactions at the first point of sale



3.2 Common bean production constraints

Common bean is prone to a number of biotic and abiotic stresses that hinder production. The insect infestation, disease and climate related production constraints are frequent and increasing. Compared to previous season, majority of farmers reported having experienced more insects, diseases and drought problems in the 2012/2013 cropping season. Insects and diseases were common across all study districts and were reported as being severe problems by over 60 percent of the households (Fig.3). Drought was also reported to be severe and relatively higher than the previous season by the majority of the households in the Muchinga province in all the three districts, Mpika, Chinsali and Nakonde (Fig 3). Generally, too much rainfall as a constraint in the study area is less severe with the exception of Kasama district in the Northern Province where 50% of the households seem to have experienced excessive rain in 2012 compared to the previous seasons.

Fig 3. Bean production constraint severity in season 2012/2013 relative to previous season



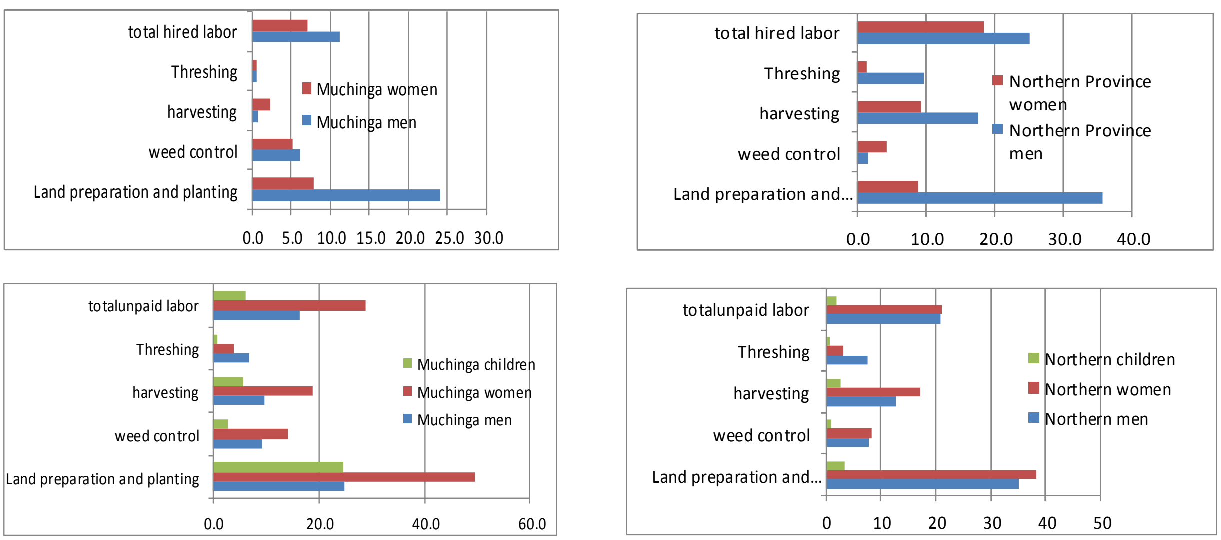
3.3 Common bean management: production inputs, intensity of use and gender roles

Main agricultural inputs used in common bean production by Zambian farmers are land, labor, and to a small extent chemical fertilizers and pesticides. Labor, mainly contributed by the family members, is the main input used in bean production. Hired labor contribution is small, about 27 percent of the total, with no significant difference between the two provinces (26% vs. 28%). Both men and women are seasonally hired to prepare, plant, and weed the land. A greater percent of hired labor constituted by men is spent on land preparation, followed by weeding (Fig 4), perhaps because these activities involve more drudgery and require more strength compared to other types of labor activities. Harvesting and threshing are rarely conducted by paid labor. Division of unpaid labor between male, female and children varies between cropping activities but not across provinces. Overall, women contribute a bigger proportion of the family's unpaid labor and mostly devoted to land preparation, weeding and harvesting. Contribution of unpaid labor by men mainly goes to land preparation.

Overall, about 9 percent of bean plots are treated with chemical fertilizers but only 5 percent of these applications are directly targeted to bean while in 3.6 percent of the plots, the application is done on the intercrops. Neither manure nor mulch is used on beans; while less than 2 percent of the bean plots were treated with insecticide; though a majority of farmers (about 78.5 percent) reported having experienced increased insect problem relative to the previous season (Fig. 3).

Figure 4: Labor (man-days/ha) intensity in bean major production activities by type and gender in 2012/2013, Zambia

a) paid labor

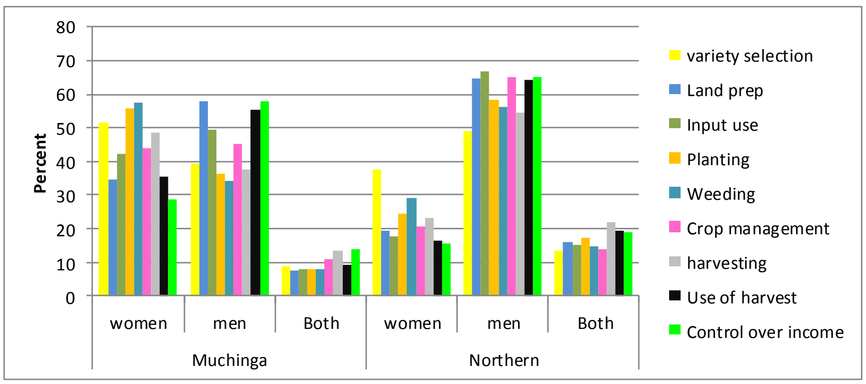


b) unpaid labor

3.4. Gender perspectives in bean production decision making

Across many countries in sub-Saharan Africa, bean production has been known to be dominated by women, hence it is often referred as a woman's crop. Contrast to this view, we found men to be the major decision makers in bean production in the study area (Fig 5). They make most of the decisions for land preparation, input use, crop management and use of harvest. In most of the households (about 60%), men also control income from bean sales (Fig 5). When compared with the labor contribution in Figure 3, a pattern of gender disparities emerge in both provinces. In Northern Province, overall family labor used in bean production is contributed equally by men and women, but men dominate the decision making. Gender disparities are more visible in case of Muchinga Province, where women contribute most of the unpaid labor (Fig.4), but men decide on the use of the harvest and control the income for most of the households (Fig 5).

Figure 5: Gender of the principal decision maker in bean production and use of bean income



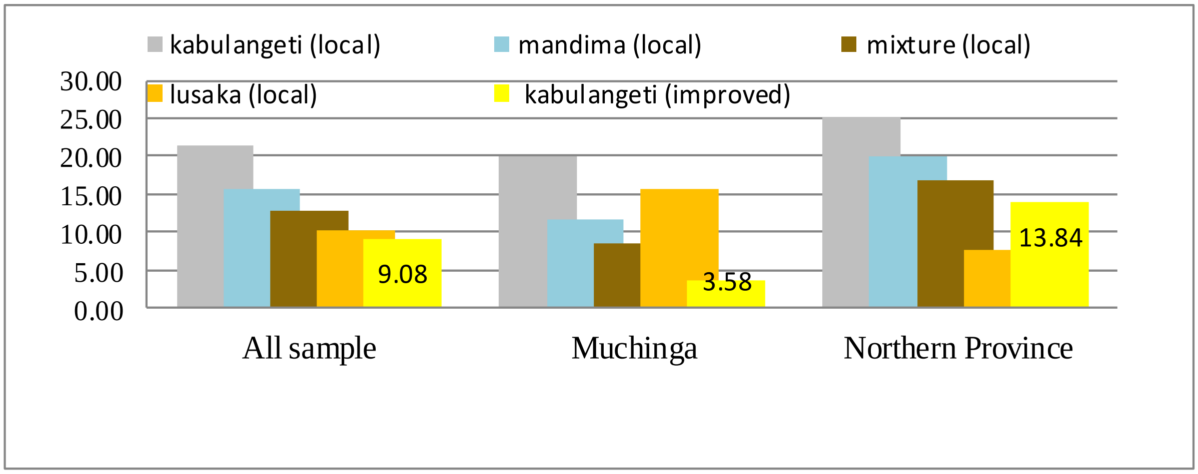
3.5 Bean varieties grown, diversity and geographical spread

In Zambia, bean is commonly grown as varietal mixtures with the most cultivated types being the bush bean produced in rotation with other crops. Recent crop production statistics show that about 472,757 households in Zambia grow mixed bean varieties (CSO, 2003). Consistent with this information, a number of distinct common bean varieties are identified in the study areas of Zambia. They comprise of improved, landraces and varieties imported through cross border trade of Tanzania. In 2012/2013 cropping season, the most important bean variety category in terms of planting frequency and area planted as categorized by the farmers were the landraces, cultivated on 84.3 percent of the bean plots and occupying an area share of 88.4 percent.

Overall and within provinces, Kabulangeti local is the most popular variety accounting for 21.5percent of the bean plots cultivated in 2012/2013 cropping season (Fig.6). Kabulangeti bean variety exists in two forms, the local and improved variety, which ranks fifth popular variety in terms of number of plots planted (9.1 percent of the bean plots). The two versions are similar in phenotypic appearance; thereby difficult for farmers to differentiate between them[3].

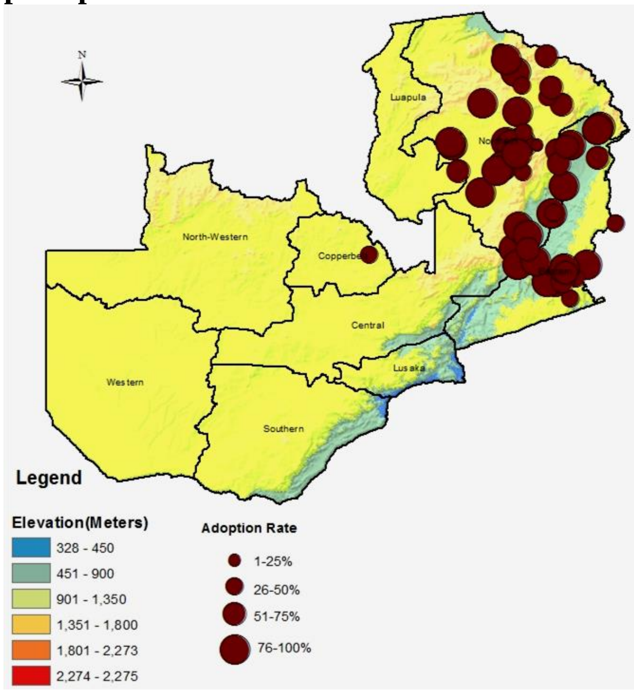
Lusaka and Mandima also landraces rank second popular varieties after Kabulangeti in Muchinga provinces, while Mandima and mixture are next popular in the Northern Province after Kabulengati local (Fig.6). These varieties are highly preferred because they are high yielding and competitive on the market. Local varieties are grown across all wards and no geographical clustering seems to emerge for the two provinces (Fig.7). Within most of the wards, over 50% of the bean plots are cultivated with local varieties in a cropping season.

Figure 6: Five popular varieties and their frequency (%) of occurrence in each province



[3] With the help of experts and seed samples, a distinction was made between the two seed type and results will be further validated based DNA finger printing method in the final report.

Figure 7: Percent of bean plots planted with local varieties in each ward



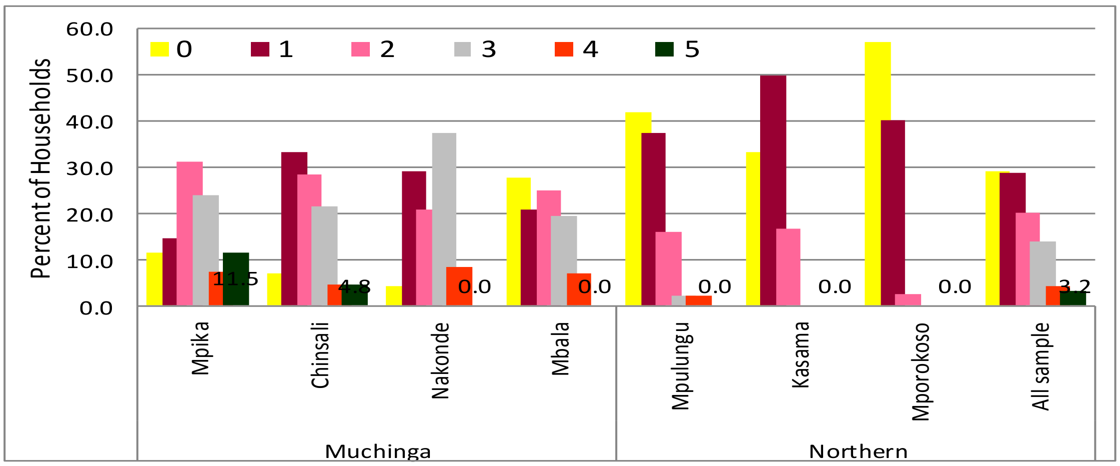
3.6 Awareness, adoption and dis adoption of improved varieties

3.6.1 Awareness, uptake and dis adoption of improved varieties

In this study, we also gathered information on farmers' histories of variety use and reasons for not planting the known improved varieties. By the time of the survey in 2013, many varieties listed in table 1 had been introduced to farmers and were registered with the Seed Control and Certification Institute (SCCI). During interviews, each farmer was asked to list all improved varieties he/she knows about irrespective whether or not the variety was grown or the year it was introduced. Further information was elicited on the source of information and reasons for none adoption if the variety was not grown. Based on responses, the sample is divided into three categories: 1) farmers who know and have ever grown the variety; 2) farmers who know but have never grown the variety and 4) farmers who do not know any improved bean variety and have never used it.

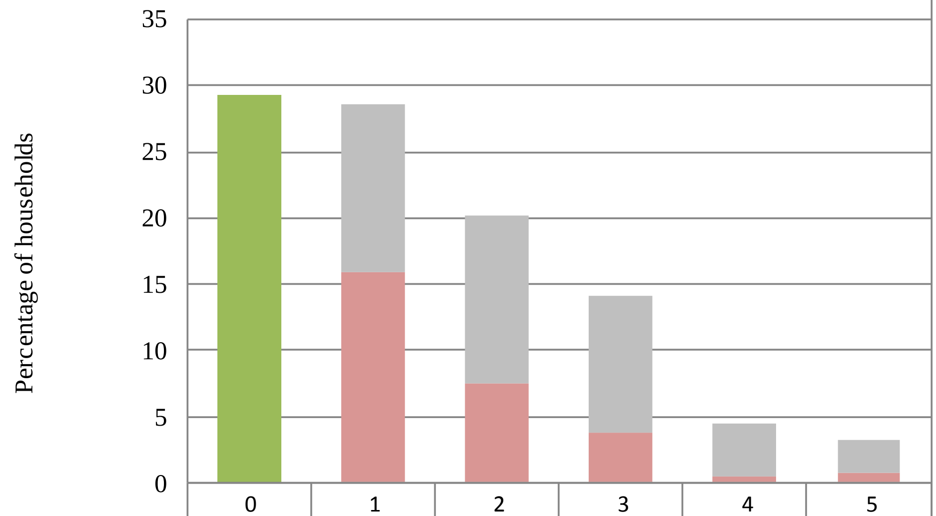
About 71 percent of the farmers are aware of at least one improved variety. Among those who know, 28.9 percent know only one improved variety and 20.3 percent are aware of two improved beans varieties (Fig 8). Overall, six improved bean varieties were known and grown by at least some farmers. The varieties included: Chambeshi, Lukupa, Kapisha, Luangeni, Lyambai and improved Kabulangeti. The improved Kabulengeti was released in 2007 and is so far the most known and frequently grown improved variety across the study area (Fig. 6). Information about improved bean varieties was frequently accessed between 2000 and 2012 when bean research and technology dissemination has been more active.

Figure 8: Number of varieties known by the sampled households across study districts in Muchinga and Northern Province



While about 70.6 percent of the households are aware of at least one improved variety, only 42.3 percent of the households have ever grown an improved variety and 28.4 percent of the households are aware but have never grown an improved bean variety (Figure 9). Lack of access to seed of improved variety is the most frequent reason for none adoption or abandonment after first planting (Appendix 1.1). Appendix 1.1 also shows that the unavailability of seed is the main underlying constraint to seed accessibility that hinders farmers from trying out a new variety. Other reasons for dis-adoption were variety specific; such as poor performance in terms of consumption or production attributes. The incidence of ever grown a new variety increases with the number of varieties known, perhaps because farmers are more motivated to try out and learn more about improved varieties when they know many (Figure 9). Hence, there is need to multiply and disseminate a diversity of varieties to farmers.

Figure 9: Percentage of households who are ware, have ever grown the varieties by number of varieties known



	0	1	2	3	4	5
not aware and never grown	29.35	0	0	0	0	0
Aware and ever grow	0	12.69	12.69	10.45	3.98	2.49
Aware but never grown	0	15.92	7.46	3.73	0.50	0.75

Number of improved varieties known

Source: survey data

3.6.2 Improved variety adoption rate and intensity of use in 2012/2013 cropping season

The rate of improved variety use per agricultural season is modest. The study results indicate that 26.9 percent of the households grew improved varieties in the 2012/2013 cropping season. The adoption of IV is not significantly different between the two provinces (Table 6). The estimated adoption rate per cropping season is far below the rate of experimentation with the technology which was reported to be 42.3 percent of the households (Fig.9). This is partly because some households abandon cultivation of the variety after experimentation and partly implies that adoption is dynamic. Some farmers may interchange varieties by season (i.e. they grow an improved variety in one season and local varieties in another season).

At plot level, improved varieties are mainly grown in a mixture with local varieties. Out of 479 bean plots in the sample, 26.3 percent were cultivated with improved varieties; about 8.14 percent of the plots planted only improved varieties and 15.87 percent planted both local and improved varieties in a mixture (Table 6).

Table 6: Percentage of households, plots; and area planted with improved bean varieties, by province

Variable	Muchinga		Northern Province		All Sample	
	N	Percent	N	Percent	N	Percent
Households level adoption	162	27.78	243	26.34	405	26.91
Plots level adoption						
No adoption	146	76.44	218	75.69	364	75.99
Full adoption	15	7.85	24	8.33	39	8.14
Partial adoption	30	15.71	46	15.97	76	15.87
Percent of area under improved varieties	191	14.7	288	16.20	479	15.6

Source: Survey data

The incidences of full vs partial adoption per plot also does not differ significantly between Provinces. In the Northern Province, about 8.33 percent of the bean plots are cultivated exclusively with improved varieties and 15.97 percent of the plots are planted with both improved and local varieties while 75.69 percent of the plots are cultivated with pure local varieties. Similarly, majority of bean plots in Muchinga are planted with local varieties while improved varieties account for 23.56 percent of the plots, 7.85 percent of which are occupied by pure improved varieties (Table 6).

Across districts, geographical patterns in the adoption of improved varieties emerge, which might imply physical specificity or bias in dissemination that has favored these districts. The adoption of improved varieties are clustered in three districts of Mbala (32.4 percent), Nakonde (30.6 percent) and Chinsali (25.5 percent) while the districts of Mpika and Mpulungu show very low adoption rate; 6.3 and 4.8 percent respectively. Overall, cultivation of improved bean varieties is widespread across wards (Fig. 10a & b), but none of the wards have the highest adoption level for pure improved varieties though few of the wards have adoption rates estimated at 51-75 percent for improved varieties in mixtures (Fig. 10 b).

Figure 10a: Percent of bean plots planted with pure improved varieties

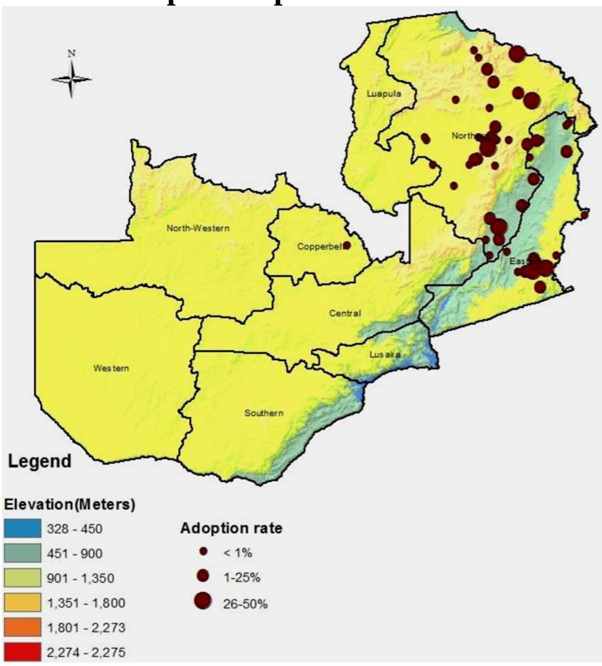
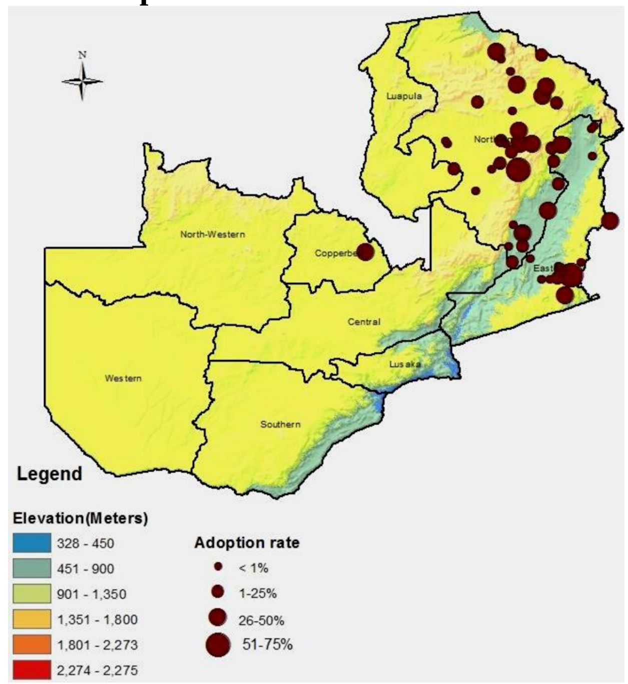


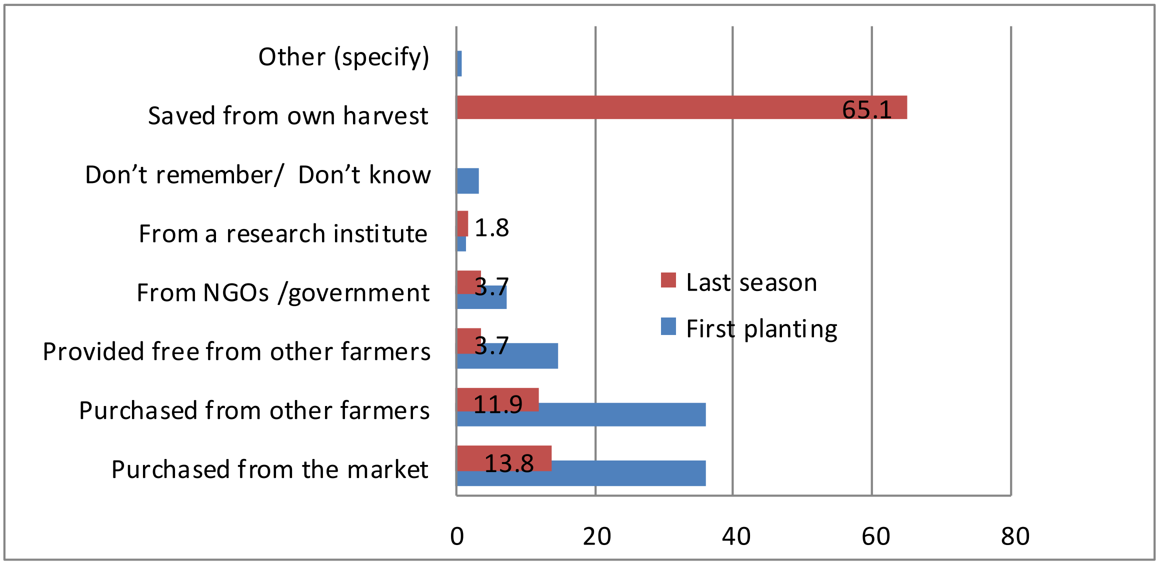
Figure 10b: % of bean plots planted with improved & local varieties mixture



3.7 Sources of information and seed of improved varieties

Farmers acquire bean seed from a variety of sources, generally consistent across districts and regions. A synthesis of farmer responses indicate that 36.9 percent and 35 percent of the farmers who are aware of improved varieties were informed about the existence of such varieties by relatives and neighbouring farmers respectively (Figure 11). Traditional social networks also play a major role in improved bean variety diffusion; used by 50.8 percent of farmers as their source seed for the first variety planting. Planting of recycled seed from own previous harvest is popular, planted in nearly two thirds of the bean plots during the 2012/2013 cropping season, while only 25.7 percent of the bean plots were cultivated with seed bought from the local market or from neighbors. Very few households received seeds from the research institute (1.8 percent) or development projects (0.24 percent), which is understandable given the low levels of investment in seed production by public institutions.

Figure11. Percent of farmers using the sources for improved bean seed at first planting and 2012/2013 cropping season, Zambia



4.0 Household profile

In this section, we describe the demographic composition and household asset endowments while comparing the adopters with non-adopters of improved bean varieties based on simple t-test and chi-square statistics. Some of these characteristics are the explanatory variables of the estimated models in equations 3 and 4, presented further on.

4.1 Household demographic characteristics

Data was elicited on different household categories by type of headship that represents the existing vulnerability context of the households. Statistics presented in Table 7 show that of the 405 sampled households, 88% were headed by males with a female spouse as a joint decision maker (i.e., had both male and female spouses as decision makers), 8% were female-headed without any adult male decision-maker, and 3% also were female headed but had an adult male decision-maker. All other households had a male head (with or without an adult female decision maker). The distribution of these household types is not statistically different between the adopters and non-adopters.

Table 7: Type and frequency of households

Household type	Non-adopters Freq.	Non-adopters Percent	Adopters Freq.	Adopters Percent	All Sample Freq.	All Sample Percent
Dual (male and female spouses)	257	86.82	98	89.91	355	87.65
Female headed with another adult male d	9	3.04	4	3.67	13	3.21
Male headed with another adult female d	1	0.34	0		1	0.25
Female headed, without any adult male d	26	8.78	6	5.5	32	7.9
Male headed, without any adult female d	3	1.01	1	0.92	4	0.99
Total	296	100	109	100	405	100

Table 8: Household demographic characteristics and assets, 2013

	Non-adopters		**Adopters**		**All Sample**	
	Mean	SD	Mean	SD	Means	SD
Age (years)	43.4	15.4	44.3	15.3	43.6	15.4
dependency ratio	0.7	0.6	0.8^	0.8	0.7	0.7
Household size	5.9	2.3	6.1	2.5	6.0	2.4
Education of household head (Yrs of formal schooling	6.8***	3.1	5.9	3.3	6.6	3.2
Gender of household head (1= male, 0=female)	0.9	0.3	0.9	0.3	0.9	0.01
Education of the spouse (yrs of formal schooling)	5.8**	2.8	5.1	2.8	5.6	2.8
Landholding (Ha)	8.9	19.9	11.6	25.9	9.6	21.7
cropped area (ha)	2.2	2.6	2.7	2.6	2.4	2.6
Household assets						
Value of livestock (Kwacha)	1089.3	3329.8	4110.7***	19901.2	1902.4	10759.8
Value of farm equip (Kwacha)	852.7	6770.3	1703.3	14172.9	1081.6	9344.1
Consumer durables (Kwacha)	921.1	1293.1	1088.0	1911.9	966.1	1484.5
Membership in association (1=yes, 0=No)	0.7	0.5	0.6	0.5	0.7	0.5
distance from tarmac road (km)	26.9	28.6	35.9	32.6	29.4	30.0
Distance from urban center (km)	55.0	38.2	55.0	29.2	55.0	35.9
Years spent in the village	19.7	14.9	19.7	15.5	19.7	15.0
Number of observations	296		109		405	

Source: Survey data

Adopters and non-adopters of improved bean varieties also have similar household demographic characteristics. A household comprises of about 6 people, with the ratio of children (0-5 years) and elderly (+65years of age) to household members between 15 and 65 being about 0.75 (Table 8). Household heads, the majority of whom are males, tend to be in their middle age (43.2 years old), about 8.6 years older than their spouses (average 35.6 years).

4.2 Household assets

Possession of assets enhances the productive capacity of the farm, propensity to absorb new ideas and take risks. In accordance with the livelihoods framework, households are regarded as possessing five types of assets (an asset pentagon) that are essential to the pursuit of livelihoods: human capital, natural capital, physical capital, financial capital, and social capital. The study results indicate that majority (90%) of the male household heads have received some form of education compared to the female household heads (65%). The average years of formal education of the household head (7.0 years) is significantly higher than that of the spouse (5.6 years) but no difference exist between adopters and non-adopters (Table 8). In Zambia, learners who leave school at primary level have problems of reading and writing English (the official language). Consequently, low levels of education constrain their ability to participate effectively in development programs including adopting new technologies as well as acquiring formal skills to pursue different livelihood options (ZARI, 2004)

Traditionally, the farming systems in Northern and Muchinga provinces of Zambia are non-pastoral. Accordingly, the size of livestock per household is small valued at an average of K.2834.4 and much smaller for non-adopters than adopters (Table 8). The average land cropped per household is about 2.5 ha using a hand hoe technology, but varies greatly and is relatively smaller for 25 percent of the households whose land holding is below 2 ha. These households cultivate one hectare or less and are at a higher risk of land degradation. No statistical difference emerged between adopters and non-adopters with regard to the size of the landholding or that of cultivated land.

Furthermore, we elicited information on the number of farm implements and value of each in its current status. Previous studies have shown that ownership of agricultural implements notably oxen, ploughs and carts are strongly associated with use of inputs such as improved seed and fertilizer in maize production for Zambia (Kumar, 1994). Unlike the study of Kumar (1994), our study did not find any significant difference between the average value of farm equipment for adopters (K.1703.3) and that possessed by non-adopters (K.852.7). The average value of consumer durable assets such as bicycles, television sets and solar panels is also the same for all household categories according to the adoption status. However, male headed households are more endowed with this kind of assets than female headed households, implying that the former are in a better position to easily access improved bean technologies than the female headed households.

Beyond individual household endowments, households in the study area are connected to social networks built around social organizations, where 66.2 percent of the households hold membership. In Zambia, organized farmer cooperatives, women associations and church based organizations have been used as conduits for agricultural input distribution and technology dissemination by most agricultural organizations. However, we found no statistically significant difference between adopters and non-adopters. In addition, each household has lived in the village for about 19 years, further contributing to the interconnectedness among households in the community.

5.0 Econometric results

In this section, we discuss the results of the econometric analysis that examine the factors that influence knowledge and adoption of improved bean varieties. Probit model with selection was used to estimate the probability that a randomly selected farmer in the study area cultivates an improved bean variety conditional on being aware of their existence. We included a dummy for extension contact as the variable excluded from the adoption equations. We expect no direct effect of extension on adoption of improved bean varieties other than through the information dissemination. Indeed, the variable is highly significant in the equation for awareness but statistically insignificant in the adoption equation. A dummy for province is also included in the awareness equation to capture the differences if any in exposure to the dissemination effort.

Diagnostic test results presented in Table 9 indicate that the model was significant at 1%, with Wald statistic chi^2 (14) of 80.66. The Wald test of independence of equations has a chi square value of 3.88 that is significant at 5 % level suggesting that awareness of improved bean varieties (our treatment) is endogenous in the adoption equation. These results indicate sample selectivity bias and evidence that both observed and unobserved factors influence the probability of being aware of improved bean varieties and the decision to adopt the improved variety outcome.

Table 9: Estimates of Probit with Selection of the probability of awareness of improved varieties and conditional adoption

	Probability of awareness (A=1)				Probability of adoption (Pr(Y=1|A=1)			
Variable	Coef	Std. Err.	dF/dx	Std. Err.	Coef	Std. Err.	dy/dx	Std. Err.
Dependency ratio	0.35**	0.13	0.069**	0.027	0.094	0.119	0.067**	0.027
Age of the household head	-0.01	0.01	-0.002	0.001	0.001	0.006	-0.001	0.001
Years of schooling household	0.06*	0.03	0.012*	0.005	-0.048^	0.025	-0.003	0.006
Gender of the household head (1=male)	0.27	0.28	0.050	0.061	0.443	0.324	0.138*	0.067
Elevation in masl					0.002**	0.001	0.000**	0.000
Base soil type sandy								
Dummy if plot soil is loam					-0.156	0.210	-0.036	0.049
Dummy (=1) if plot soil is clay					-0.807**	0.268	-0.188**	0.059
Access credit (1=yes)					0.313	0.282	0.073	0.065
Distance (km) from tarmac	-0.01*	0.00	-0.002*	0.001	0.010**	0.003	0.001^	0.001
Distance (km) from urban	0.01**	0.00	0.001*	0.001	-0.012**	0.003	-0.002**	0.001
Dummy =1 if chemical fertilizer is used	-0.66*	0.32	-0.173*	0.089	-0.675^	0.381	-0.242**	0.072
Value of livestock	0.001*	0.00	0.000^	0.000	0.000	0.000	0.000*	0.000
Number of different varieties per plot					0.418**	0.106	0.097**	0.020
Dummy=1 if household possess a mobile phone	-0.19	0.19	-0.037	0.030			-0.024	0.025
Dummy=1 if household access any extension training	0.47**	0.18	0.089**	0.036			0.061*	0.025
Dummy =1 if any household has membership in farmer group	0.28	0.19	0.059^	0.033			0.036	0.023
Dummy =1 if Muchinga province	1.32**	0.23	0.236**	0.047			0.169**	0.036
Constant	-0.95^	0.57			-3.657**	1.012		
Athrho	-1.133*	0.576						
Rho	-0.81	0.196						
Log pseud likelihood	-326.5							
Number	421							
Wald chi2	80.66**		105.82**					
Wald test eqn chi2 (rho=0)	3.88*							
R2			0.234					
Observed probability			0.773					
Predicted probability			0.889					

5.1 Determinants of probability of awareness

The estimates of the factors that affect the probability of being aware and adopting improved bean varieties are provided in Table 9 along with standard errors clustered at the household-level. As expected, the probability of being aware about the improved varieties varies among households according to their geographical location (Muchinga vs Northern Province), household characteristics and degree of remoteness. Households in the Muchinga Province are more likely to acquire information on improved bean varieties than their counterparts in the Northern Province, perhaps reflecting the intensity of exposure in the former. The study results are consistent with the literature that the cost of information acquisition reduces with education of the decision maker (see Feder et al., 1985). The likelihood of being aware of at least one improved bean variety is higher among households headed by individuals with more years of schooling. A one more year spent schooling from the mean increases the probability that a household is aware of improved bean variety by 1.2 percentage points (Table 9).

Demand side effects as well as supply factors emerged as important determinants in information access. Results indicate that a one point increase in the ratio of dependents (i.e. household members below 15 years and those above 64 years of age) to the number of household members aged 16 to 64 years (productive members) positively and significantly increases the probability of knowing improved bean varieties by 6.7 percentage points, which can probably be attributed to the risk of food insecurity and hence the desire to increase bean production that drives decision makers to seek information. On the other hand, households with access to alternative strategies for soil fertility management such as chemical fertilizers were 17.3 percent less likely to be aware of improved bean varieties, which is not surprising since improved varieties were developed to adapt to poor soil conditions and serves as substitutes to non-varietal options. On the supply side, information dissemination mechanisms notably extension services and membership in farmer association dummies were found to be positively correlated with access to information about improved varieties, which is expected since these two factors facilitate the diffusion of information on agriculture technologies. Market conditions, captured by distance to nearest tarmac road and urbanity, though significantly correlated with the likelihood of knowing an improved bean variety, their effect was too small and hence less important.

5.2 Determinants of adoption of improved beans varieties:

The second stage of the simultaneous probit provides the estimated coefficients and marginal effect for the adoption functions which are also reported in table 9. The marginal effects show the combination of direct and indirect effect of the variable on the probability of adoption.

Results reveal that soil quality of the bean plot and households' access to alternative soil fertility management strategies are the most important factors that explain the probability that a plot pre-allocated to bean production will be cultivated with improved bean varieties. The probability that improved varieties will be adopted reduces by 18.8 percent for a move from plots of sandy soil quality to plots of clay soil type. This suggests that new improved bean varieties are better adapted to sandy soils than clay soils. Similarly, the study results indicates a reduction of 24.2 percent in the probability of cultivating improved varieties among households that use chemical fertilizers as compared to those who do not use chemical fertilizers, which implies that the two inputs are substitutes. This can be interpreted to mean that farmers that use chemical fertilizers may be able to overcome the soil constraints and obtain higher or same yields from local varieties, hence less motivated to adopt improved varieties. On the other hand, adoption of improved varieties significantly increases with variety diversity, further highlighting the fact that farmers that prefer variety mixture over pure stands are more likely to be attracted to new improved bean varieties as they would like to enrich their mixtures with new varieties.

Consistent with the literature (Feder, et al., 1985, Feder and Umali, 1993), our study reveals that household demographic characteristics influence adoption of improved bean varieties. Households headed by males are 13.8 percent more likely to adopt improved bean varieties than those headed by females. This is contrary to findings from Rwanda (Sperling et al., 1995) and Southern highlands of Tanzania (Letaa et al., 2014) where the likelihood of adopting improved bean varieties has been observed to be neutral to gender of the household head. Female headed households depend largely on social networks for the seed of improved varieties and when diffusion of improved varieties in these social networks is still low, it means that female households experience more constraints with regard to accessing seed of improved varieties than male headed households. Household assets such education influences adoption through its effect on information acquisition while household wealthy (represented by value of farm equipment, livestock) do not seem to be important in the adoption of improved bean varieties.

6.0 Conclusions and Discussion

In Zambia, bean is an important crop that provides food and cash income to the producers but crop productivity is constrained by insect pests, diseases and drought which seem to be on the rise. Bean research to address these constraints started way back in 1950s and intensified in 1982 by a grain legumes research program with financial support from FAO/UNDP and CIAT. This effort has since resulted in several varieties adapted to pests and diseases, low soil fertility and acidity while accounting for user preferences. This study has analyzed the adoption and diffusion of these varieties. The study also describes the bean management systems of Zambia, severity of production constraints, crop ranking, marketing and varieties grown. A probit model with selection was used to estimate the factors that influence access to information on these technologies and the probability that conditional on being aware, the farmer chooses the improved variety over local ones.

The study found a number of varieties released by the ZARI known and used by farmers in the study communities but their adoption in terms of percentage of bean producing households and area occupied is modest. In aggregate, about 27 percent of bean producers are cultivating improved varieties, allocating a total of 15.6 percent of the area pre-allocated to the production of these varieties. A number of factors explain the observed adoption of improved varieties. In particular, the importance of information acquisition facilitating factors such as extension, social capital in form of membership in association, in the awareness equation highlight uneven access to technology that constrain adoption. Hence, there is need to expand on variety dissemination targeting a range of varieties to provide farmers with a wide choice.

In addition, a significant percentage of farmers that are aware of the improved bean varieties have not adopted largely because seed is either not available to facilitate experimentation and eventual adoption or unaffordable for some farmers. More surprising is the finding that lack of seed is also a frequent reason provided for dis-adoption. The problem of seed access can be partly attributed to the fact that most of the farmers add new varieties to the existing mixtures, which limits the area allocated to seed of improved variety and consequently constrains the ability of early adopters from bulking sufficient seed to facilitate subsequent diffusion on the farm as well as community through farmer to farmer exchange of seed.

Results also show that variety specific characteristics and adaptability to physical environment play an important role in the adoption. The significant reduction in the probability of adoption as soil quality changes from sandy to clay suggests limited adaptability of the improved varieties also reflected by high rate of dis-adoption due to low performance such as low yields, poor taste, etc of varieties. In all the selected study districts, farmers experience increasing production constraints, which, reflects changes in the physical environment. Bean improvement research should continue to be supported to enable further adaptation of varieties to the changes in the environment and physical conditions where constraints are currently increasing.

Finally the study results suggest a substitution effect from non-varietal soil fertility management options such as access and use of chemical fertilizers, offering support to the breeding for resistance and adaptability to physical conditions, as a pro-poor strategy to sustain bean production. Therefore, efforts to ensure that poor farmers obtain access to the technology will contribute significantly to the nutrition of the poor and poverty reduction objective.

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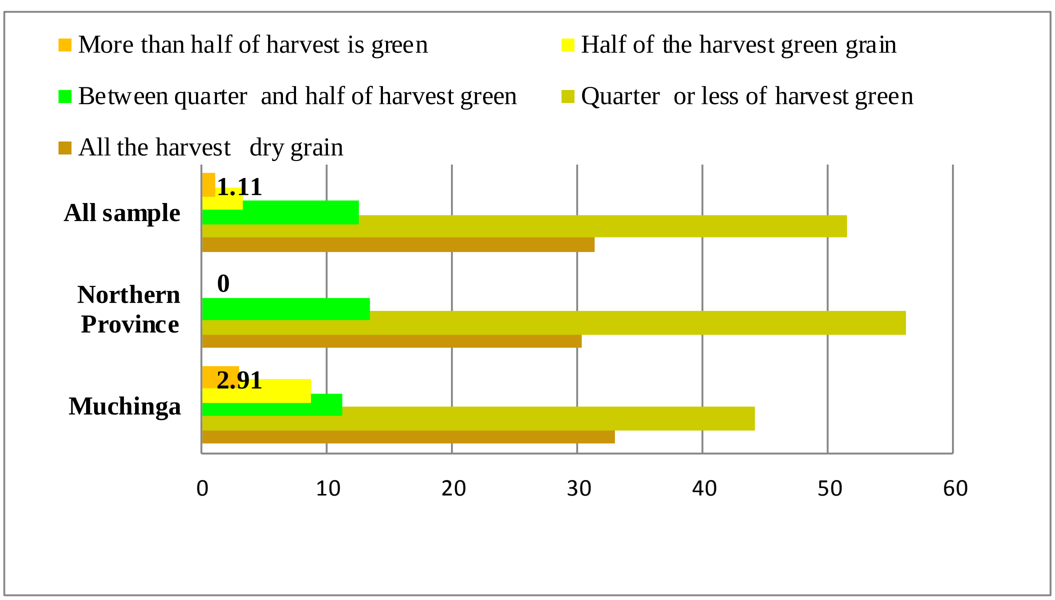
Appendices:

Appendix A1.1: Reasons provided by farmers for never adopted or dis-adopting improved varieties

Reasons	Never planted		Ever planted and dis-adopted	
	Freq.	Percent	Freq.	Percent
Seed related problems	**235**	**81.31**	**112**	**53.33**
Seed not available	210	72.66	94	44.76
Lack of cash to buy seed	25	8.65	18	8.57
variety related reasons	**44**	**15.24**	**81**	**38.57**
I prefer other varieties	16	5.54	10	4.76
Low price received for the variety	8	2.77	9	4.29
Low yielding variety	7	2.42	30	14.29
No market	11	3.81	15	7.14
Requires high skills	1	0.35	6	2.86
Variety had poor taste	1	0.35	4	1.9
Variety matured late			7	3.33
Other reasons	**10**	**3.46**	**17**	**8.11**
labor demanding			1	0.48
Lack access to credit	8	2.77	12	5.71
Lack of land to experiment			1	0.48
lack of rain			1	0.48
Other (specify)	2	0.69	2	0.96

Appendix A1.2: Proportion of bean harvested as green pods (%)



Appendix A1.3: Point of first sale and type of buyer from producers (%)

Marketing	Muchinga	Northern	All
place of transaction			
Farm gate/home	49.62	73.91	65.54
Village market	21.8	10.67	14.51
Main/district market	28.57	15.42	19.95
type of buyer			
Farmer group	0.75	3.57	2.34
Farmer Union or Coop		0.4	0.52
Consumer or other farmer	60.15	19.84	33.77
Rural assembler	3.01	4.76	4.16
Broker/middlemen/trader	27.82	45.63	39.48
Urban wholesaler	8.27	23.41	18.18
Exporter		1.59	1.04
Other (specify)		0.79	0.52