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Farmers' use and adaptation of improved climbing bean production practices in the highlands of Uganda

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ABSTRACT

Climbing beans offer potential for sustainable intensification of agriculture, but their cultivation constitutes a relatively complex technology consisting of multiple components or practices. We studied uptake of improved climbing bean production practices (improved variety, input use and management practices) through co-designed demonstrations and farmer-managed adaptation trials with 374 smallholder farmers in eastern and southwestern Uganda. A sub-set of these farmers was monitored one to three seasons after introduction. About 70% of the farmers re-planted climbing beans one season after the adaptation trial, with significant differences between eastern (50%) and southwestern Uganda (80–90%). Only 1% of the farmers used all of the improved practices and 99% adapted the technology. On average, farmers used half of the practices in different combinations, and all farmers used at least one of the practices. Yield variability of the trials was large and on average, trial plots did not yield more than farmers' own climbing bean plots. Yet, achieved yields did not influence whether farmers continued to cultivate climbing bean in the subsequent season. Uptake of climbing beans varied with household characteristics: poorer farmers cultivated climbing beans more often but used fewer of the best-bet practices; male farmers generally used more practices than female farmers. Planting by poorer farmers resulted in adaptations such as growing climbing beans without fertilizer and with fewer and shorter stakes. Other relationships were often inconsistent and farmers changed practices from season to season. The diversity of farmer responses complicates the development of recommendation domains and warrants the development of a basket of options from which farmers can choose. Our study shows how adoption of technologies consisting of multiple components is a complicated process that is hard to capture through the measurement of an adoption rate at a single point in time.

1. Introduction

The East African highlands are densely populated, and decreasing farm sizes and declining soil fertility status require agricultural intensification to sustain food production and avoid encroachment into forests (Benin et al., 2002; De Bauw et al., 2016; Sassen et al., 2013). The integration of legumes in farming systems provides a pathway for sustainable intensification of agriculture (Giller and Cadisch, 1995; Snapp et al., 2002b). Common bean is an important staple crop in many East African countries and a source of protein, calories, minerals and vitamins. Climbing beans offer potential to intensify bean production compared with bush beans, with yield potential being their greatest advantage: up to 4–5 t ha^{-1} (Checa et al., 2006) versus 1 to 2 t ha^{-1} for bush beans in Uganda (Kaizzi et al., 2012). Climbing beans are also more resistant to fungal and root rot diseases (Mcharo and Katafiire, 2014), and have a better potential to fix nitrogen (Bliss, 1993; Ramaekers et al., 2013; Wortmann, 2001). Improved varieties of climbing bean were introduced in Rwanda in the 1980s (Sperling and Muyaneza, 1995) and were rapidly adopted, particularly in the highlands of northern Rwanda. Climbing beans spread from Rwanda to neighbouring countries such as Burundi, DRC and Uganda in areas above 1600 m above sea level (masl) (Franke et al., 2016).

Climbing beans are not a simple replacement of bush beans as the latter are often intercropped with maize or grown as an understory in banana-coffee systems. Elsewhere, in Latin America, maize and climbing bean intercropping is common (Clark and Francis, 1985; Davis and Garcia, 1983), but in African systems where elevation is lower climbing beans grow too fast and smother the maize. Climbing beans are therefore better grown as sole crops. In addition, climbing beans need stakes to realize their climbing potential, implying additional costs

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for materials and labour. Moreover, because of their larger biomass production, climbing beans require more nutrient inputs (Sperling and Muyaneza, 1995). Altogether, adopting climbing beans constitutes a relatively complex change in farming practice and is not a mere replacement of cultivar.

Best yields of climbing bean are achieved through a combination of practices: the use of improved varieties, phosphate fertilizer and organic fertilizer, row planting, sole cropping, a high density of strong and tall stakes, timely planting and proper weeding (Franke et al., 2016; Kaizzi et al., 2012). Given the heterogeneity of African smallholder farming systems, these practices and their optimal combination (together representing the 'climbing bean technology') need to be tailored to fit the local agro-ecological, socio-economic and cultural environment (Descheemaeker et al., 2016; Giller et al., 2011). As argued for other complex technologies consisting of multiple components, it is unlikely that all farmers would adopt all components, or that adoption takes place as a simple, linear process (Brown et al., 2017; Glover et al., 2016).

In this study, we used the outcome of a co-design process with farmers, extension officers, NGOs and researchers to introduce improved climbing bean production practices among smallholder farmers in the highlands of eastern and southwestern Uganda. Farmers applied these practices on their own field in a so-called 'adaptation trial' and were monitored during and after the trial. Feedback from farmers' experimentation and their adaptation of the technology, and understanding the reasons for (non-)use of practices in subsequent seasons provides insight in the adoption process and dynamics over time (Doss, 2006).

We also explored the relationship between the use of climbing bean production practices and a range of agro-ecological, plot and household characteristics. Variables selected were largely based on previous work on understanding the heterogeneity of African smallholder farming systems (Giller et al., 2011; Tittonell et al., 2005, 2010), and on adoption studies of agricultural technologies (Feder and Umali, 1993; Kassie et al., 2015; Knowler and Bradshaw, 2007) and legumes (Farrow et al., 2016). Agro-ecological characteristics are important to determine the biophysical relevance of technologies (Farrow et al., 2016). Plot characteristics such as land tenure, soil fertility and soil depth are often considered in relationship with the willingness to invest in improvement of the land (Banadda, 2010; Kassie et al., 2015; Kerr et al., 2007). Household characteristics (demographics, access to capital and labour, production orientation and importance of farm/off-farm income) define farmers' ability to implement new technologies (Feder and Umali, 1993; Marenya and Barrett, 2007; Pircher et al., 2013). We also considered farmers' previous experience with the technology, as decisions to use a certain practice may be related to earlier choices (Cowan and Gunby, 1996; Kassie et al., 2013).

Our objective was to understand the change in climbing bean production practices and the reasons for these changes among farmers of different geographical areas and socio-economic backgrounds, and to use this understanding to inform technology re-design and to delineate recommendation domains. We hypothesized that the majority of farmers would not adopt all components of the climbing bean technology, and that the use of practices would be related to performance of the adaptation trial, household wealth and farmers' previous experience with the practices.

2. Methodology

2.1. Study area

The study was conducted in Kapchorwa District in eastern Uganda, located between 34.30° and 34.55° East and 1.18° and 1.50° North, and Kabale and Kanungu Districts in southwestern Uganda, located between 29.60° and 30.30° East and 0.35° and 1.50° South. The study sites are situated in the highland areas of Uganda, around 1800–1900 masl (Table 1). Both have two rainy seasons per year, and average annual rainfall in Kapchorwa district is 400–500 mm more than in the other two districts. Other important differences between the districts include soil type (of volcanic origin in Kapchorwa district and parts of Kanungu district, and Acrisols in Kabale district), market access, population density and experience with climbing bean cultivation, although the latter also differs within districts.

Table 1
Characteristics of study sites in eastern and southwestern Uganda.

	Southwestern Uganda		Eastern Uganda
District	Kabale	Kanungu	Kapchorwa
Elevation (masl)	1800	1850	1900
Rainfall (mm)[a]	1100	1200	1600
Cropping season A	Feb-Jun	Feb-Jun	Mar-Jul
Cropping season B	Aug-Nov	Aug-Nov	Sep-Dec
Soil type[b]	Acrisols	Acrisols/ Andosols	Andosols
Distance to main market	Medium: 1.5 to 2 h (dirt road)	Poor: 2.5 to 3 h (dirt road)	Good: 1 to 1.5 h (tarmac road)
Population density (people km^{-1})[c]	207	57	297
Experience climbing bean cultivation	Medium	Long	Short

[a] climate-data.org.

[b] www.soilgrids.org.

[c] www.ubos.org.

2.2. Dissemination of the climbing bean technology

The study was conducted in the context of the N2Africa project. The climbing bean technology (combination of improved variety, input use and management practices) was disseminated in the format of 'mother and baby trials' (Snapp, 2002), whereby a large demonstration plot facilitated learning and comparison of a range of treatments throughout the season, and small trials enabled the testing of one treatment on farmers' fields. In this study we call these 'demonstration' and 'adaptation' trials respectively.

Demonstration trials showed a number of varieties, inputs, staking methods and other agronomic management practices. Treatments for these demonstration trials were developed in a co-design process with farmers, researchers, extension officers and NGO staff over a total of four seasons in 2014 and 2015 (see Descheemaeker et al. (2016)). The demonstrations started with a number of practices distilled from researchers' experiences. Farmers evaluated the practices, which served as input for a re-design session with all stakeholders in which practices were modified, added or discarded to develop a 'basket of options' (Giller et al., 2011). Treatments in the demonstration therefore varied over locations and seasons (Supplementary material, Table S1). However, every season it was ensured that a 'researcher best-bet' and a control treatment were included.

We defined the *researcher best-bet technology* as the combination of practices that is expected to give the best climbing bean yield, and which was based on previous research on legumes in general and climbing beans specifically by Uganda's National Agricultural Research Organisation (NARO) and project staff. The researcher best-bet technology consisted of the following components: an improved climbing bean variety with cattle manure and Triple Super Phosphate (TSP), planted as sole crop and in rows spaced at 50 cm between rows and 25 cm between plants, 2 seeds per hole (i.e. a density of 160,000 plants per ha), 40,000 stakes per ha and stakes taller than 1.75 m. The control treatment had the same variety and management practices but was planted without manure and TSP. The researcher best-bet and the control both had single, wooden stakes.

Because climbing beans were new for many farmers in Kapchorwa and poor availability of stakes due to deforestation was mentioned as