Understanding drivers behind the implementation and adaptation of improved climbing bean (*Phaseolus Vulgaris* L.) technologies by smallholder farmers in Kapchorwa district, Eastern Uganda

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MSc Thesis
Plant Production Systems – N2Africa
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Table of contents

Summary

In Uganda, increasing pressure on arable soils demands for options that improve food security and enhance its fertility. One way to achieve this is by exploiting legume technologies. In this study we look at improved climbing bean technologies like the application of phosphorus fertilizers or the use of improved climbing bean varieties to enhance soil fertility and increase food security. Getting farmers to make more use of these technologies is however not an easy task. Within the evolution of a technology, making sense of the evaluation of the technology is an important part of the evolution but has thus far been relatively poorly described. To achieve adoption of a technology it is important to understand what farmers drives in adopting new technologies, and also what caused the farmers to adapt the technology to finally lead to an adoption most fit for local conditions. A project that aims to bring this iterative process into practice is the N2Africa project. The project monitors if and how farmers implement demonstrated practices and if they make any adaptations to them. The project therefore provided smallholder farmers with a package consisting of improved climbing bean seeds, phosphate-fertiliser, and planting guidelines, which they could implement and adapt to their own needs. This gave the farmers the opportunity to use and manage the improved varieties in the way best suitable for their household conditions, resource endowments and production orientation.

In this study, we focused on implementation and adaptation of improved climbing bean-technologies by farmers who received a package. Therefore 88 smallholder farmers were interviewed, who were situated in four different sub-counties in Kapchorwa district, Uganda. Firstly, we found that seeds should be disseminated in time for the project for the farmers to be able to plant them, and farmers should not be restricted in the way they are to plant the beans. Secondly, most farmers planted the climbing beans in intercropping with mostly banana and coffee instead of in sole cropping and poorer farmers planted more in random planting, which saves labour during planting compared to row planting. Thirdly, a trend is found that farmers with small farm sizes apply more often manure than farmers with larger farm sizes, and additionally, staking availability is still poor in the area. To optimize (the use of) climbing bean technologies in this area, more research could be done on the intercropping of banana and coffee with climbing beans. Furthermore, low-cost alternatives for manure or mineral fertilizer could be promoted, like compost or crop residues. Furthermore, extension officers could be better monitored in order to give farmers in different locations demonstrations as similar as possible and to make sure the demonstration plots are managed and treated similarly.

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1 Introduction

In Uganda, 72.4% of the labour force works in the agricultural sector, of which the largest share is subsistence farming (FAOSTAT, 2014). The population has been growing exponentially since 1961 (Expansión, 2014) and prevalence of malnutrition has increased from 27% in 2000 to 35% in 2012 (FAO, 2014). Although Uganda has long been regarded as a country which has fertile soils, land degradation is now a serious problem, mostly resulting in loss of productivity (Andersson, 2014). This productivity loss increases the chances of food insecurity, especially when facing an annual population growth of 3.24% in 2015 (CIA, 2014).

The increasing pressure on arable soils demands options that improve food security and do not further deplete the soil, but enhance its fertility. One way to achieve this is by exploiting legume technologies. Legumes are able to fix atmospheric nitrogen in a symbiotic relationship with rhizobia (soil bacteria). Rhizobia can infect the root of a legume, where after the legume forms nodules around the bacteria. Within these nodules, rhizobia fix N_2 from the atmosphere to form ammonium (NH_4^+), which the plant uses for growth. In return, the plant feeds the rhizobia with assimilates.

For legumes, the genotype of the legume and the rhizobia nodulating the legume are of importance. The grain and biomass production of a certain legume therefore depends on the formula:

$$(G_L \times G_R) \times E \times M$$

where G_L is the genotype of the legume, G_R the genotype(s) of the rhizobia nodulating the legume, E the environment and M the management (Giller et al., 2014). Therefore, environmental constraints (like nutrient deficiencies in soils, drought or waterlogging) and also management practices (like use of mineral fertilizer, sowing dates, plant density and weeding) influence the total grain yield of the legume. The only treatment that shows consistent responses in N-fixation and grain yield is the application of P (Giller, 2001). Therefore, adding extra P to the system is necessary to increase legume productivity.

An important staple crop in Uganda is the common bean (*Phaseolus vulgaris* L.). Common beans can be either bush beans or climbing beans. The yield potential of climbing beans is higher than that of bush beans: 3.5 to 5 ton/ha, which is threefold the yield of bush beans (Musoni et al., 2014; Ramaekers et al., 2013). Although farmers in Uganda cultivate common bean, most of them plant bush beans, or local varieties of climbing beans, which do not have the yield potential and nutrient benefits that improved climbing bean varieties have (Sperling & Muyaneza, 1995). Improved climbing bean technologies like the application of phosphorus fertilizers or the use of improved climbing bean varieties are therefore an option available to farmers to increase their productivity and at the same time enhance their soil fertility. However, getting farmers to make more use of these technologies is not an easy task.

In the past, improved agricultural technologies were often offered as 'top-down' blanket recommendations. The adoption of these recommendations was generally poor (Kiptot et al., 2007), mainly because such recommendations do not take into account the large heterogeneity of farming systems and farm types. This heterogeneity can be related to soil fertility (Tittonell et al., 2005) but also to resource endowments (Amrouk et al., 2013), household characteristics (Vanlauwe et al., 2014) and production orientation of farmers (Tittonell et al., 2005).

The need to develop technologies that reflect the realities of farmers' fields is therefore generally accepted (Ojiem et al., 2006). However, the fact that still many technologies have not been adopted despite attempt to respect farmers' preferences shows that this endeavor is faced with difficulties (Aker, 2011). For example, participatory experiments can capture farmers' preferences, but do not directly reflect if, why and especially how farmers actually implement or adapt the technology that will eventually lead to adoption (Pircher et al., 2013).

Therefore, technological development should go through an iterative process to eventually develop technologies that best fit the local resources and preferences of farmers (Giller et al, 2008; Giller, 2013; Jakku & Thorburn, 2010). This iterative process is described by Douthwaite et al., (2002) who provide a framework that is used to explain farmers' adoption and rejection of agricultural technologies. Evolution of technologies has to go through repetitive phases of participatory evaluation of technologies, to create options that fit best in the local environment. These phases are 1) experience, 2) making sense, 3) drawing conclusions, 4) actions, and then again 1) experience. Within this evolution of a technology, the evaluation of the implementation and adaptation of the technology, the 'making sense', plays an important role. However, this evaluation has thus far been relatively poorly described (Douthwaite et al., 2002). To achieve adoption of a technology it is therefore important to understand what farmers drives in adopting new technologies, and also what caused the farmers to adapt the technology to finally lead to an adoption most fit for local conditions.

A project that aims to bring this iterative process into practice is the N2Africa project. N2Africa is a development-to-research project that is focused on enhancing the use of nitrogen fixing grain legumes by smallholder farmers in SSA. Beginning with the right legume crop for a specific region, determined by using the socio-ecological nice concept developed by Ojiem et al., (2006), a 'basket of options' of improved legume technologies is introduced in the target area. This 'basket of options' is introduced through a demonstration trial in which different treatments are shown, originally based on existing best management practices. Best practices that are adapted to take local resources into account are offered in the demonstration trial as well. In so-called 'adaptation trials', farmers can test these best management practices on their own field. The project monitors if and how farmers implement these practices and if they make any adaptations to them. For the adaptation trials in the Eastern highlands of Uganda, farmers receive a package consisting of improved climbing bean seeds, phosphate-fertiliser, and planting guidelines, which they could implement and adapt to their own needs. This gives the farmers the opportunity to use and manage the improved varieties in the way best suitable for their household conditions, resource endowments and production orientation.

In this study, we focus on implementation and adaptation of the improved climbing bean-technologies. We avoid using the term adoption, as this is often defined as the use of a certain technology for several seasons (Kamanga et al., 2014; Kiptot et al., 2007). In this research we only monitored the implementation of technologies during one season. Moreover, farmers were given the package, so we cannot speak of independent adoption. Adaptation, in this context, is defined as 'the modification of a climbing bean-technology that makes it more suitable for application under local conditions'. This adaptation is a continuous process, and can occur in many phases in the progress towards adoption. Because the environment is expected to change over time and farmers are seen as 'moving targets' (Giller et al., 2011), the introduced technologies are constantly adapted to these new environments. This happens in both the process of implementation, as well as during the more 'final' stage of adoption of the technology.

Adaptations that farmers make in the adaptation trials can be taken into account when re-designing demonstration trials for new seasons. Farmers have reasons to use or not to use new technologies, and researchers can work together with farmers to create practices that are tailored to specific regions and farm types, creating options that best fit their local context. Therefore, it is necessary to monitor and evaluate these adaptation trials by first looking at the degree of implementation and adaptation of demonstrated technologies, and secondly at the determinants for this implementation or adaptation to be able to target the right groups with the right adjustments to improved technologies. Finally, to see if phosphate-fertilizer application, biophysical factors or farmers from different wealth groups also translate into differences in production, yields need to be compared.

The first objective of this research is therefore to assess to what extent farmers implement and adapt any of the demonstrated climbing bean technologies in the Eastern highlands of Uganda. The second objective is to find determinants for the implementation and adaptation of the demonstrated climbing bean technologies. The third objective is to find factors that could be related to differences in yield. To answer these objectives, the following research questions and hypotheses were defined:

1. To what extent did farmers implement or adapt the N2Africa technology package and any of the practices that were demonstrated in the N2Africa demonstration trial?

2. What determines the implementation or adaptation of the technology package and the demonstrated practices?

    Hypothesis: The degree of implementation of technologies is often positively correlated to resource endowment (Sietz & Van Dijk, 2015; Tittonell et al., 2010). Therefore farmers with fewer resources are less likely to have implemented any of the demonstrated practices.

3. What are differences in yield between:
    a. Plots with and without phosphate-fertilizer

        Hypothesis: Plots where phosphate-fertilizer is applied yield higher, because phosphate fertilizer increases grain yield of legumes (Giller, 2001).

    b. Sub-counties

        Hypothesis: Biophysical factors like temperature and rainfall influence yield performances. Therefore farmers in higher altitude sub-counties have higher yields than farmers from sub-counties in lower altitudes.

    c. Farm types

        Hypothesis: Differences in production orientation and resource endowment influence soil fertility. Therefore yields are different between different farm types (Tittonell et al., 2005).

The results of these research questions will be used to reflect on which practices are (not) implemented, and how they are adapted, to formulate what researchers can learn from farmers' implementation and adaptation of the demonstrated practices and how this could influence future demonstration trials, and/or research questions.

2 Methodology

2.1 General characteristics of the research area

This research was conducted in Kapchorwa district in Eastern Uganda, close to the Kenyan border (Figure 1). Kapchorwa is situated on the slopes of Mount Elgon (Figure 2) at altitude levels between 1500-2200m above sea level (asl), in one of the main areas in Uganda with good potential for growing climbing beans due to its favourable biophysical conditions: climbing beans grow well in a long growing season (up to 200 days), a long seed filling period (nearly 50 days), when there is sufficient rainfall (evaporation losses are compensated) and when temperatures are moderate (around 17-22°C) (Graham & Ranalli, 1997; Gross & Kigel, 1994).

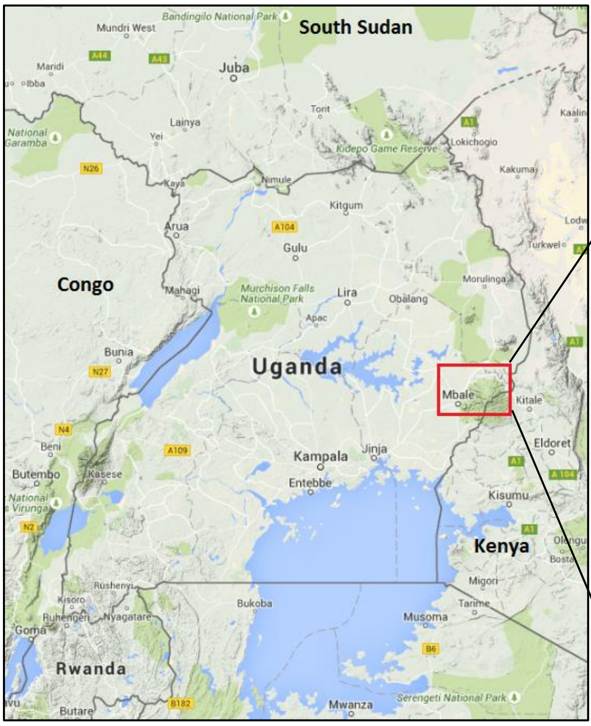

Figure 1. Uganda and neighbouring countries. The area marked in red indicates the study area

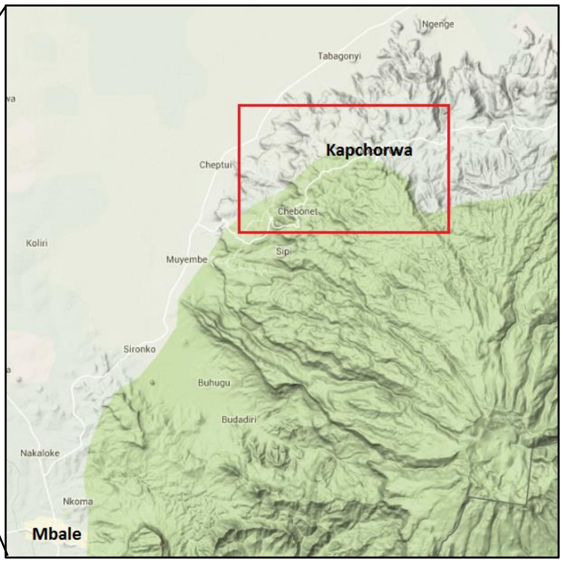

Figure 2. The area marked in red indicates Kapchorwa district on the slopes of Mount Elgon. The green area is a national park.

The research area consists of four sub-counties: Kapchesombe, Kaptanya, Chema and Tegeres. These sub-counties are further divided into parishes. Next to administrative boundaries, the study area can also be divided according to altitude in an upper and lower belt, with a tarmac road serving as a rough separation. Therefore, in each sub-county, we made a distinction between parishes/farmers situated in the lower and upper belt; the contour line of 1900m asl provides this geographical division (). Kapchesombe and Kaptanya sub-counties are located on the eastern side of Kapchorwa town. Kapchesombe is situated in the upper belt, while Kaptanya is situated in the lower belt of the district. The paved road from Mbale to Kapchorwa stops just beyond this town, which made Kaptanya and Kapchesombe only reachable by dirt roads and more difficult to reach during rainy days. Chema and Tegeres are oblong sub-counties, which stretch from 1200m up to 3300m asl while the slopes are gentle, averaging less than 4° (Sassen & Sheil, 2013). At the narrowest points, the borders of the sub-counties are only 2km apart, as the crow flies. Chema and Tegeres consist of both an upper and a lower part. The upper parts of these sub-counties were only reachable by very steep dirt roads, which made them hard to reach during heavy rainfall. Because larger differences were expected between the lower and upper parts of these sub-counties than between Chema and Tegeres sub-counties itself, the upper and lower parishes of Chema and Tegeres were grouped together.

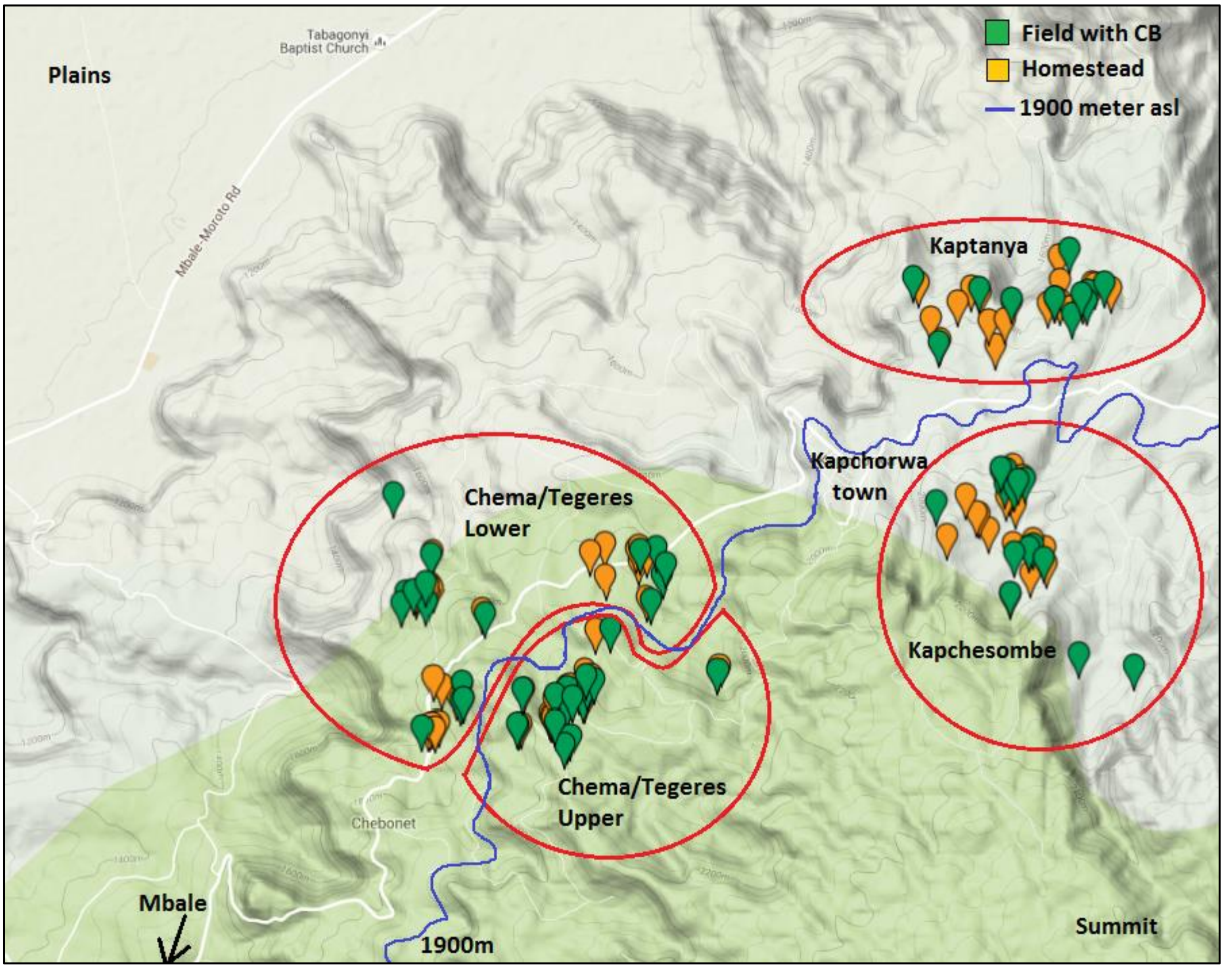

Figure 3. Map of the sub-counties in Kapchorwa district, where interviews were held in the homestead (orange) and in the field (green). The blue line shows the contour line for 1900meter asl. The green area is part of the national park.

The average altitude of the homesteads of the lower parishes is 1802m asl and for the upper parishes 2020m asl. Farmers who planted the beans in the lower parishes did this at lower altitudes than their homestead, with an average of 1783m asl. The farmers in the upper parishes planted their beans at the same average altitude as their homestead: 2020m asl.

Soils in the research area are of volcanic origin, and are mainly luvisols, but phaeozems and kastanozems are also found in the lower regions, as well as andosols in the higher altitudes (ISRIC-World Soil Information, 2014).The farming system most present in the research area is a Montane system, which is found at higher elevations: above 1500m asl. The major staple crop grown throughout the year is plantain (cooking banana, local *Musa* varieties), but sweet potatoes (*Ipomoea batatas)*, cassava (*Manihot esculenta)* and Irish potatoes (*Solanum tuberosum* L.*)* are also cultivated. At higher altitudes, coffee (*Coffea arabica)* and more temperate crops like wheat (*Triticum* spp. L.*)* and barley (*Hordeum vulgare* L.*)* can also be found (FAO/GIEWS, 2014a). Kapchorwa has a bimodal cropping season. The first season for beans starts halfway March and ends in June, while the second season starts in September and ends in January. The first season is the main cropping season. This research was conducted in the second season of 2014 (season 2014B).

Average annual rainfall in Kapchorwa District between 2007 and 2013 was 1078mm (FAO/GIEWS, 2014b). July-August and December-February are relatively dry, although rain falls in all months (Sassen & Sheil, 2013). Rainfall data for the four sub-counties was collected during the time of study (2014B) with rainfall gauges, which were read daily by extension officers (local farmers who work for the project). There was no rainfall data available for Kapchesombe sub-county. Compared with the 2007-2013 average, rainfall was moderate in

Kaptanya with an annual rainfall of 1283mm in 2014, while in Chema upper the rainfall was heavy, with over 1900mm with three months of data missing (January, February and March) (Figure 4).

Temperatures in Kapchorwa district average around 18.5 °C, with minimum temperatures around 12.0 °C and maximum temperatures around 25.1°C. On average, February is the warmest month, while July is the coldest (Climate-Data, 2015).

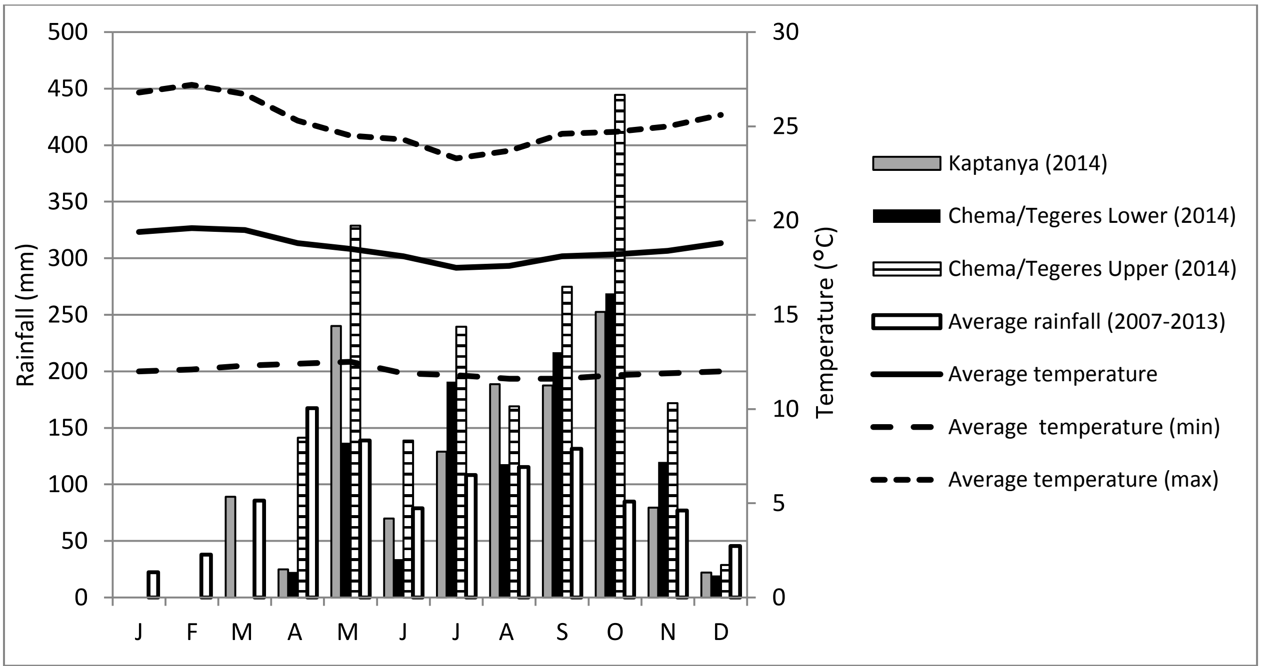

Figure 4. Rainfall in Kaptanya and the upper and lower parishes of Chema and Tegeres in Kapchorwa district (collected rainfall data, 2014) compared with the average monthly rainfall in Kapchorwa between 2007-2013 (FAO/GIEWS, 2014b). Rainfall data for the first three months from Chema and Tegeres are missing.

The population density of Kapchorwa district is around 169 people per km^2, which is just below the national average of 174 people per km^2. The population density for Tegeres is slightly lower than the district average with 123 people per km^2, Chema has about 227 people per km^2, and Kaptanya around 203 people per km^2 (which is more than the national average). Kapchesombe is seen as a parish from Kaptanya, so the same population density holds for Kaptanya and Kapchesombe (UBoS, 2006a, 2006b).

2.2 The N2Africa project in Kapchorwa district

Climbing beans have been grown for several decades in Eastern Uganda (Wortmann et al., 1998), but the number of farmers growing climbing bean on Mt Elgon is still very low (UBoS, 2010). The N2Africa project first started in Kapchesombe and Kaptanya sub-counties in 2013, the two sub-counties with the smallest percentage of farmers that cultivated climbing beans in Kapchorwa district at that time. After two seasons the project expanded to new areas to reach more farmers and the sub-counties Chema and Tegeres were selected. The first introduction of climbing beans in these sub-counties had happened prior to the project – farmers form these districts have actually been growing climbing beans for a longer time than those in Kaptanya and Kapchesombe. But although famers already grow climbing beans, they use local varieties with few inputs (Wortmann et al., 1998), so there is potential for intensification of climbing bean cultivation by introducing new varieties, the use of phosphate fertilizer, and use of other improved practices like optimal planting densities or row planting.

2.3 Demonstration trials

Within the N2Africa project, demonstration trials are used to show farmers a basket of options of improved climbing bean technologies. Kapchorwa district had 15 demonstration trials in season 2014B. These demonstration trials were established on-farm and collaboratively managed by researchers and farmers. Planting was done according to the protocol for climbing bean demonstrations in Kapchorwa district (Appendix I). The objectives of the demonstration trials were: 1. To demonstrate a range of climbing bean technology options, focusing on different varieties, inputs and staking methods; 2. To compare the performances of technology options in terms of biomass and grain yield; 3. To evaluate the impact of biophysical conditions on the performance of the technology options.

Each demonstration trial contained 11 treatments (Table 1). Treatments consisted of two varieties of climbing beans, planted with different (combinations of) inputs and best management practices. These best management practices were mainly based on the leaflet "Growing improved climbing bean varieties for higher productivity", developed and distributed by NaCRRI et al. (2013). The treatment combining the improved variety NABE 12C with cattle manure, Triple Super Phosphate (TSP) and single stakes was considered the 'researcher best-bet'. All demonstrations used bamboo as staking material for the single stakes. Next to this an alternative low cost staking method was provided, because farmers mentioned staking to be the major constraint in the area. In this treatment the bamboo stakes from the researcher best-bet treatment were replaced by poles of eucalyptus with half sisal strings and half banana fibre. Furthermore, tripods were another alternative option, aimed at enhancing yields as stakes would not easily fall over. In Chema and Tegeres, four of the demonstrations also included maize stalks as staking material. Maize was planted in the first season and their stalks were used for staking, which is a method that was adapted from local practices found in farmers' fields. Each treatment was planted with 2 seeds per hole and 4 plants per stake. The leaflet from NaCRRI prescribes one seed per hole, but as this did not reflect the farmers' reality in the field, 2 seeds per hole were advised.

Table 1.Lay-out of treatments found at demonstration sites in Kapchorwa. Dark highlighted cells are recommended best management practices that enhance climbing bean productivity; light highlighted cells are alternative staking methods. The encircled row (Treatment 8) shows the treatment consisting of only best management practices and is seen as the 'researcher best-bet'.

Treatment	Variety	Cattle manure	TSP	Staking method
1	Local Kabale	-	-	Single stakes
2	NABE 12C	-	-	Single stakes
3	Local Kabale	+	-	Single stakes
4	NABE 12C	+	-	Single stakes
5	Local Kabale	-	+	Single stakes
6	NABE 12C	-	+	Single stakes
7	Local Kabale	+	+	Single stakes
8	**NABE 12C**	**+**	**+**	**Single stakes**
9	Local Kabale	+	+	Tripods
10	NABE 12C	+	+	Tripods
11	NABE 12C	+	+	Half sisal/ half banana fibre

2.4 Best management practices for climbing bean cultivation

For the analyses in this research, nine best management practices were selected that were offered in the demonstration trials, and which are considered to increase farmers' production. These best management practices are mainly based on the leaflet "Growing improved climbing bean varieties for higher productivity", developed and distributed by NaCRRI et al. (2013). These practices are:

1. Sole cropping;
2. Row planting (to ease field operations);
3. Phosphate fertilizer (TSP);
4. Manure application;
5. Weeding twice during the season;
6. 2 seeds per hole;
7. Sowing density of 160.000 plants ha^{-1} (80.000 holes with both 2 seeds);
8. Staking density of 40.000 stakes ha^{-1} (4 plants per stake);
9. Stakes longer than 1.75m

The degree of implementation and adaptation of these nine best management practices in farmers' adaptation trials are analysed in this research, together with the implementation of the alternative staking methods (tripods, sisal strings and banana fibres). Determinants for the implementation or adaptation of these nine best management practices were also analysed.

2.5 Adaptation trials

For the adaptation trials, farmers were provided with a package from N2Africa, including seeds of the improved climbing bean variety (NABE 12C) and phosphate fertilizer (TSP). Farmers who received such a package are hereafter referred to as 'adaptation farmers'. Together with this package, farmers received an instruction leaflet (Appendix II). They were asked to plant two separate plots of 5X5m: one with the improved variety without TSP, the other plot with the improved variety with TSP. Farmers themselves could decide to implement one of the other demonstrated practices: plant density, manure application, staking, weeding and pest and disease control, which they were informed about during planting of the demonstration trials.

2.6 Sampling of farmers

Of the 271 adaptation farmers who received a technology-package at the start of season 2014B, initially 80 farmers were randomly selected to do surveys with. Farmers who were interviewed are hereafter referred to as 'focal farmers'. Because climbing beans were expected to grow better in higher altitudes, the two different altitude levels were sampled with an equal amount of farmers. Therefore 40 farmers were selected from both the lower and higher altitudes (Table 2). At least two parishes were selected per sub-county, and at least 5 farmers per parish, to ensure stratified random sampling.

Table 2. Initial sampling framework used to select farmers in the different sub-counties.

	Number of farmers		
	Lower	Upper	Total
Chema	10	10	20
Tegeres	10	10	20
Kaptanya	20	NA	20
Kapchesombe	NA	20	20
Total	40	40	80

The selection of farmers was done by randomly selecting farmers from a random selection of parishes within each sub-county. However, not enough farmers were available to get a total of 20 farmers on the upper part of Chema and Tegeres together, since there were not more farmers available than the farmers that were already selected. Therefore in the end, 19 farmers from the upper parishes in Chema (n=7) and Tegeres (n=12) were selected, alongside 26 from the lower parishes of Chema (n=18) and Tegeres (n=8). From Kapchesombe 21 farmers were selected; from Kaptanya there were 22.

Although farmers were asked to plant two clearly distinguishable plots, one with and one without inputs, only 16 farmers planted in two plots. Originally, 40 farmers who planted two distinguishable plots should have been selected from the 80 farmers to provide yield data. However, because not enough farmers planted in two different plots, researchers attempted to find farmers who planted two distinguishable plots among the other 191 farmers who initially received a package. Most farmers did not plant in two plots, so only an additional 8 farmers were found. Out of the total 88 interviewed farmers, 24 farmers planted in two plots.

For harvest measurements, farmers who planted two plots were selected first, so that harvest measurements between the control plot and the plot with TSP could be compared. Of the 24 farmers who planted in two plots, 19 were selected for harvest measurements: because only three farmers from Chema/Tegeres Upper planted two plots, the sample size for this area became too small for meaningful statistical analyses. Therefore none of the farmers who planted beans in Chema/Tegeres Upper (n=16) were selected for harvest measurements. Two other farmers with two plots planted different varieties of beans. An additional number of farmers with only one plot was selected, to collect enough harvest data to be able to do statistical analyses. From Chema/Tegeres Lower, 7 farmers were selected who planted in two plots and 5 who planted in one plot. From Kaptanya, too, 7 farmers were selected who planted in two plots and 3 who planted in one plot. From Kapchesombe, 5 farmers were selected who planted in two plots, and 7 who planted in one plot. A total of 19 farmers with two plots were selected, and 15 with one plot. There were no more farmers available that matched the requirements for harvest measurements.

2.7 Participation in demonstration trials in previous seasons

The degree of participation differs between Chema and Tegeres, and Kapchesombe and Kaptanya: previous participation in Chema and Tegeres means that farmers visited and evaluated a demonstration trial a couple of times during the first season of 2014 (2014A). This demonstration had similar treatments as demonstration trials in 2014B, and farmers could have observed row planting, sole cropping, the use of inputs and alternative staking methods (sisal string, banana fibre and tripods). Focal farmers who participated in a previous season in Kapchesombe and Kaptanya may have participated in the same way (visiting and evaluating a demonstration trial in season 2014A). However, a number of farmers also already participated in season 2013A or 2013B, when the N2Africa project worked with small demonstrations of four treatments on farmers' fields. Farmers in

Kapchesombe and Kaptanya may therefore have tested some of the technologies on their own field before, in a more intensive way than a visit to a demonstration trial.

2.8 Data collection

For data collection, the N2Africa field book for adaptation trials was used (appendix III). This field book consisted of two parts: one part describing data collection that could be conducted at the homestead, and another part that was focused on the field. In both parts, additional questions were added, focused on this research and climbing beans specifically.

Answers to the questions in the field books were noted down on a tablet. The first part, conducted at the homestead, had questions focused on farmers' resource endowment, production orientation and other household and farm characteristics. The second part was conducted in the field and only with the farmers who planted the beans. Questions were asked about the practices they had used and their reasoning for applying these practices. Agronomic measurements were done in the adaptation trial plot and in the control plot, if this was available. Stake length, stake density, distance between rows and plants and plot size were all measured with a tape measure of 30m. Soil depth was measured using a soil probe of just over a meter in length, and depths were measured op to 0.5m. A local interpreter was present at these interviews when necessary.

After harvest, farmers were visited again to measure the yield, where possible of two different plots. Farmers were asked to keep their harvest separate twice: first when the interview was conducted and once again at a later stage, when the farmers selected for harvest measurements were called and instructions were repeated. The harvest was measured using a small kitchen scale.

2.9 Data analysis

2.9.1 Analysis of quantitative data

Quantitative data analysis was done in the (statistical) software package R (3.2.2). Additional packages that needed to be installed and that were used for this analysis were: the package "xlsx" (Read, write, format Excel 2007 and Excel 97/2000/XP/2003 files), to read data from Excel, the package "agricolae" (Statistical Procedures for Agricultural Research), to do further analyses on Anova's, the package "MASS" (Support Functions and Datasets for Venables and Ripley's MASS), to be able to do analyses on ordered factors, and the package "predictmeans" (Calculate Predicted Means for Linear Models), to visualise means for linear models.
Analysis of Variance (ANOVA) was used to detect statistically significant differences between determinants of (non) implementation or adaptation of demonstrated practices, and between resource endowments, household characteristics, production orientation or location properties. Ordered factors such as farm types were taken into account by making use of a generalized linear model (glm) instead of a linear model (lm), because these groups are based on a range (e.g. form poor to wealthy). When differences between two ordered factors were to be detected, a proportional odds logistic regression (polr) was used to be able to do the right analyses. Fischer's exact test was used to establish the significance of the association between two kinds of classifications, like row planting and if they participated in an earlier season or not, because it tests for independence, and because the expected frequency in any cell in the contingency table was less than 5.

2.9.2 Analysis of qualitative data

The motivation behind (non-)implementation and adaptation of best management practices was analyzed by grouping and labelling the answers given by the farmers. The reasons behind (non-)implementation and adaptation are described in percentages. These percentages were derived by dividing the number of farmers mentioning a certain category of reasons over the total number of farmers in the specific sub-group that was analysed (e.g. number of farmers who did intercropping). Farmers were allowed to give more than one answer.

2.10 Construction of Farm types

Farms and their households were divided into four farm types. An estimate of the farmers' wealth class was made in the field, based on a number of observations and surveyed household characteristics. This estimated wealth gave a first rough classification into four farm types, ranging from very poor to wealthy. Secondly, to decrease observer bias and to make the groups more homogeneous, each farmer was evaluated separately on a few different factors, based on the factors Marinus (2015) used for farm typology. These factors were the size of the farm, the total number of livestock of each farmer, expressed in tropical livestock units (TLUs) (Jahnke, 1983), the number of cattle they owned, valuable goods owned, production orientation, and the most important source of income, which were all estimated values given by the farmers. Furthermore the type of housing was also taken into account: poorer farmers stayed in houses constructed of semi-permanent walls with a thatched roof, while wealthy farmers stayed in houses constructed of permanent walls and an iron sheet roof, which was observed at the homestead. Add one or two sentences on how this changed your first rough typology.

3 Results

The first section of this chapter describes to what extent the focal farmers planted the N2Africa technology packages (improved beans and phosphate fertilizer), and implemented and adapted any of the practices from the demonstration trials. The second section focuses on the determinants of this implementation and adaptation, and uses the nine best management practices from the researcher best-bet that were described in paragraph 2.5 as a basis. In the third section, climbing bean yields are compared between the two plots, and between different groups of farmers.

3.1 Implementation and adaptation of the N2Africa technology packages

From the 88 farmers that were interviewed, six farmers planted only part of the beans and stored the other part, while 20 other farmers did not plant at all (Table 3). The 26 farmers who did not plant (part of) the beans had several reasons for not doing this. Half of these farmers mentioned that they received the seeds too late to be planted 'right'. In addition, a lack of space (15%) was mentioned, which was indirectly caused by the late distribution of the beans, since it meant other crops already occupied the farmers' fields. The second reason was more related to weather conditions: 38% of the farmers delayed their planting due to too much rain, waterlogging or drought. The third most frequently mentioned reason was illness or pregnancy (31%). Other reasons were the presence of free-range chickens which could eat the beans (n=1), and lack of knowledge about what to do with the beans (n=1). Finally, 12% of the farmers kept the beans, because they were planning to plant the beans in the dry season by making use of irrigation. By irrigating the beans, the farmers could sell fresh beans when not many farmers would be selling beans, which means they could sell them at a higher price.

From the 68 farmers who did plant, eight farmers had problems with the beans soon after planting. Four of these eight farmers mentioned that chickens and donkeys ate all the emerging beans. Three others mentioned waterlogging, too much rain or drought as the main problem for their losses. These eight farmers are therefore not included in the analysis on management practices, although they had initially planted.

Table 3. Total farmers interviewed, farmers who planted in two different plots and farmers from whom harvest data from two different plots was collected, per sub-county.

Sub county	Total farmers	Planted	Planted in two plots	Measured harvest	Measured harvest from two plots
Kapchesombe	21	15 (71%*)	6 (40%**)	7	3
Kaptanya	22	11 (50%*)	7 (64%**)	5	1
Chema/Tegeres Upper	19	16 (84%*)	3 (19%**)	0	0
Chema/Tegeres Lower	26	18 (69%*)	8 (44%**)	9	4
Total	88	60 (68%*)	24 (40%**)	21	8

*Percentage of total farmers
** Percentage of farmers that planted

Of the 60 farmers who planted, 24 planted in two plots as indicated in the instruction leaflet (Appendix II). Several farmers planted two plots to see potential yield differences between the two plots. However, most farmers ran out of fertilizer, and continued planting the beans without fertilizer and without clearly indicating when mineral fertilizer application had stopped. The reasons given by farmers to explain why they planted only one plot were mainly that they did not know they were asked to plant in two plots (19%), that they did not receive enough seeds to plant in two plots or lacked the time and space to do so (17%), or that they had enough fertilizer for the whole plot (n=2). Other farmers did not receive TSP (n=1), received two varieties of beans (n=1), wanted overall good yields (n=1) or planted two plots without knowing where each started (n=1).

For harvest measurements, 19 farmers with two plots were selected. From eight farmers harvest was measured in the end. Four others harvested only one plot and the resulting seven had nothing to harvest: three farmers had their beans eaten by chickens and goats, two were not encountered at their house and did not pick up their phone, and two had no yield due to late planting and drought. From the 15 farmers who were selected with only one plot, the harvest of nine farmers was measured. Three could not be reached, and the other three had either eaten the beans fresh and weighted part of the beans with pods (n=1), or had their beans eaten by livestock before harvest (n=1) (Table 3).

All focal farmers who planted and applied the TSP (n=53) applied it in the planting hole, together with the beans. About 51% stated that the beans grow better and give higher yields with mineral fertilizer, and 40% applied the TSP because they were told to do so. Only 8% of the farmers mentioned to have applied the fertilizer in order to see the difference between the two plots.

Of the seven farmers who did not apply TSP, three did not receive TSP from the project staff and did not have enough money to buy TSP. Other reasons mentioned were having too little to plant with the beans (n=1), it being the first time cultivating the beans (n=1), rains making fertilizer useless (n=1) or being told to plant without TSP (n=1).

While farmers were instructed to plant in two plots of $25m^2$, farmers planted in plot sizes ranging between $7.26m^2$ and $544.00m^2$ with an average of $88.49m^2$ per plot.

3.2 Implementation and adaptation of the demonstrated practices

For the analyses in this section only the data gathered from farmers who planted the beans are used (n=60). Any variations are explicitly mentioned. Farmers who planted in two plots applied the same management practices on both plots, apart from TSP application. Therefore only the fields with TSP are analysed.

In the demonstration trials, practices were demonstrated that are a better alternative to increase yield or offer an alternative to high costs or low availability of stakes (Table 4). There were no practices that were used by all farmers. Furthermore, none of the farmers used all best management practices from the researcher best-bet.

Table 4. Demonstrated practices and the percentage of focal farmers implementing these practice (n=60). For the implementation of TSP n=56, because only 56 farmers received TSP in their package. If farmers adapted a practice, a description is given about this adaptation.

Demonstrated practice	Implemented by farmers	Adaptation description
Sole cropping	27%	Most farmers intercropped with banana and coffee (73%).
Row planting	58%	Planted in grids; similar distance between rows and plants. The rest was planted randomly (42%).
Phosphate fertilizer use (n=56)	93%	Mostly on the whole field, not in separate plots (68%).
Manure application	13%	
Weeding twice during the season	13%	Weeding done mostly once (57%), never thrice.
2 seeds per hole	32%	Mostly 3 or more seeds (58%).
25cm plant spacing	3%	Plant spacing was more similar to row spacing, 54cm average.
50cm row spacing	29%	
Sowing density (320-480 in 5x5m)	13%	Plant density was lower than the density in the demonstration trials. An average of 290 plants per 5x5m emerged.
Staking density (100 per 5x5m)	17%	Average: 57 stakes per 5x5m.
Stake length (>1.75m)	42%	42% of the farmers also selected on stake length, but there was no correlation between stake length and the farmers selecting based on stake length.
4 plants per stake	21%	Low staking density resulted in a slightly smaller number of plants per stake. Average: 3.7 plants per stake.
Staking method (single)	85%	Normal practice for climbing beans.
Staking method (tripods)	7%	Single stakes supported by smaller stakes, forming a 'tripod' (n=4).
Staking method (sisal strings or banana fibre)	0%	Wooden construction with wooden/bamboo stakes leaning against it, instead of sisal strings or banana fibre (n=1).

Even though climbing beans were planted as a sole crop in the demonstration trials, most farmers planted in an intercropping system. Farmers planted in sole cropping because they were told to by the project (38%), or to attain good yields (19%). Other farmers mentioned this was the only land available (n=2) or to protect the beans from competition with other crops (n=1).

Of the farmers who did intercropping, 75% planted the beans with banana (Plantain, *Musa*), 45% with coffee (*Coffea arabica)*, and 23% with cassava (*Manihot esculenta)*. Small percentages were intercropped with Eucalyptus (*Eucalyptus)* or food crops like cabbage (*Brassica oleracea)*, cocoyam (*Colocasia esculenta)* or potatoes (*Solanum tuberosum* L.). Reasons to do intercropping with beans were mainly: a shortage of land (57%), the other crop already growing there (34%) or that particular field having more available space compared to other fields (14%). Two farmers wanted to provide shade for the beans and two others intercropped with maize (*Zea mays*) and cassava, which were simultaneously used as stakes for the beans.

Manure was used by 13% of all farmers. Only one farmer applied the manure because he saw it in the demonstration trial, four farmers mentioned they added manure to strengthen the soil and one other mentioned manure is a normal practice. Reasons for farmers not to apply manure (n=47) were mainly that they either could not afford it or did not have access to it (53%), or they had already applied mineral fertilizer, which made adding extra manure unnecessary (15%). Two farmers applied the manure on a different field or crop and four farmers mentioned to have fertile soils already. Other reasons mentioned were: that manure causes blight (n=1), mineral fertilizer was cheaper (n=1), that the plot was not theirs (n=1), and illness (n=1).

Weeding was done by a majority of the farmers (70%); however, 81% only weeded once. A small portion of the farmers weeded a second time (19% of the farmers who weeded), and none of the farmers weeded a third time. Farmers were only asked for dates of weeding, so no reasons for the number of times of weeding were recorded.

On average, farmers planted 2.98 seeds per hole. 10% planted 1 seed, 32% planted 2 seeds, and 58% planted 3 or more seeds. The farmers' who planted two seeds did this mainly because they saw it in the demo or were told to plant two seeds (37%). Also, by planting more seeds, at least some would remain if others died (21%). Other reasons heard were that it was a normal practice (n=2), to get higher yields (n=2), that they already planted less seeds than normal (n=2), that they did not have enough stakes (n=1), or that they were trying to give the beans enough space (n=1).

From the farmers who planted 1 seed, five mentioned that they were told to plant like that and saw it in the demo, and one other farmer wanted to give the beans enough space. Reasons for farmers to plant 3 or more seeds per hole were mainly because if others died, some would still remain (30%), that more beans per hole are a normal practice (21%), that they did not have enough stakes (15%), and that what they planted was already less than what they normally plant (n=3). The latter was influenced by the lower sowing densities, which they had observed in the demonstration trial. By planting 3 or more seeds the farmers were also expecting higher yields (n=3), and the space for planting the beans or fertilizer to apply with the beans was limited (n=3).

Reasons for farmers to plant in rows were mainly to get easier access to their beans - for easier staking, weeding, spraying and planting (47%). Others stated that they did it because they observed this practice at the demonstration trials (37%), or that they were trying to give the beans enough space to grow (22%). Reasons to not plant in rows and instead use random planting were primarily that it is a normal practice (42%), that the farmers had no time to plant using a different method (21%), or that there were other crops (maize or banana) already in the field (17%) which made random planting the easiest option.

Most farmers used single staking in their adaptation trials. Half of the farmers used single stakes because these were available, or because they said to "have no other option". Another 14% were not familiar with any other method. Other farmers mentioned that single staking needs less stakes than other methods (n=4), it is a normal practice (n=3), it is an easy way of staking (n=3), or that single stakes give good yields (n=2).

Four farmers used a mix of single stakes and tripods. Tripods were made in all cases to strengthen or support the single stakes. None of the farmers used the alternative low-cost sisal strings or banana fibre. However, one farmer made a construction similar to the wooden construction for the sisal strings in the demonstration trials, but with a height of about 1 meter. Instead of the strings he used wooden sticks or maize stalks. He used this construction to give more support to the wooden sticks and maize stalks (Figure 5).

Figure 5. On the left a tripod is created to support the single stake. On the right a wooden construction supports wooden sticks and maize stalks.

Most farmers used a mix of different staking materials like Eucalyptus (*Eucalyptus)*, Coffee (*Coffea arabica)*, Bamboo (*Bambusoideae*), Maize (*Zea mays*), and local trees (35%). Some farmers used only local trees (30%) or maize (17%). Four farmers used only Cassava (*Manihot esculenta)*, Eucalyptus or Bamboo. One farmer mentioned that his beans were now staked with maize stalks since the eucalyptus poles he initially used were stolen by people who use it for firewood.

Of the farmers who staked, 52% grew less than 3.5 plants per stake. Around 21% grew between 3.5 and 4.5 plants per stake and 27% grew more than 4.5 plants per stake. Staking densities were lower than in the demonstrations trials, because still many beans in the field were left unstaked.
Four farmers did not stake because of illness and hospital visits (n=3). One farmer did not stake because at the time of staking, no money was available and yield was not promising, so the farmer lost hope (n=1).

Stake length varied between 130cm and 235cm in the farmers' fields. The average stake length was 175cm, and 58% of the farmers used stakes that were on average smaller than 175cm. Therefore, 42% of the farmers had stakes of 175cm or longer. Also 42% of the farmers selected stakes based on their length. These farmers, however, did not overlap: there was no significant difference in average stake length between farmers who did select on stake length (177.6 m) and the ones who did not select on stake length (171.6m) (*p*=0.636).

3.3 Implementation of pest control

Another important management practice that influences yields for climbing beans is the control of pests and diseases. Although no practices to control these were demonstrated in the trials, farmers do experience problems with pests and diseases and use different methods to control them. Out of all the farmers, 65% experienced problems with pests. Of the farmers experiencing pests, 59% sprayed with pesticides, and they only started using pesticides when the beans were already infested with pests. Of the farmers who had pest problems, 74% had problems with aphids, 28% with caterpillars and 21% with bean flies. Other small occurring pests were termites, moles, (wild) birds and goats. Of the farmers who did not spray any pesticides (n=37), 41% said not to have enough money to buy pesticides, 32% had no problems with pests, and other farmers gave up on their beans (8%), or had no time for spraying pesticides (5%). Some of the farmers protected their beans by creating scarecrows to keep away wild birds or chickens. They attached plastic bags to strong wooden poles, trees or bushes that were present around the bean plot. To overcome problems with chickens during and shortly after planting, farmers tied their chickens (Figure 6).

Figure 6. A chicken tied to a wooden bench

3.4 Determinants of implementation and adaptation

To find determinants for implementation and adaptation, we focused on the nine best management practices that were shown in the researcher best-bet (see section 2.4).

Differences between farmers such as their resource endowment (farm size, housing, etc.), household characteristics (number of household members, education, etc.), and production orientation are expected to influence the implementation or adaptation of these best management practices. To deal with these differences, we grouped farmers into farm types. Furthermore, where possible, specific indicators like farm size or ownership of cattle were also viewed in relation to implemented practices.

Biophysical and geographical differences were expected to influence the implementation or adaptation of the best management practices as well. We expected differences in implementation between sub-counties, related to differences in biophysical factors that are influenced by altitude and previous participation in the project

(Kapchesombe and Kaptanya where the project started one year earlier, versus Chema and Tegeres). Again, specific indicators like altitude, earlier use of climbing beans and whether or not the farmers visited the demonstration site or not were also analysed in relation with implementation of the practices. Whether farmer visited the demonstration trials or not, could be influenced by geographical location because extension officers who distributed the technology package worked in different sub-counties.

We first describe the different farm types and geographical locations, followed by an analysis of how these characteristics determine the implementation of the demonstrated technologies.

3.4.1 Farm types

Farmers were categorized into four farm types, ranging from very poor (farm type 1 (FT1)) to wealthy (farm type 4 (FT4)). Most farmers belonged to farm type 2 (FT2) and the smallest amount of farmers belonged to FT4 (Figure 7).

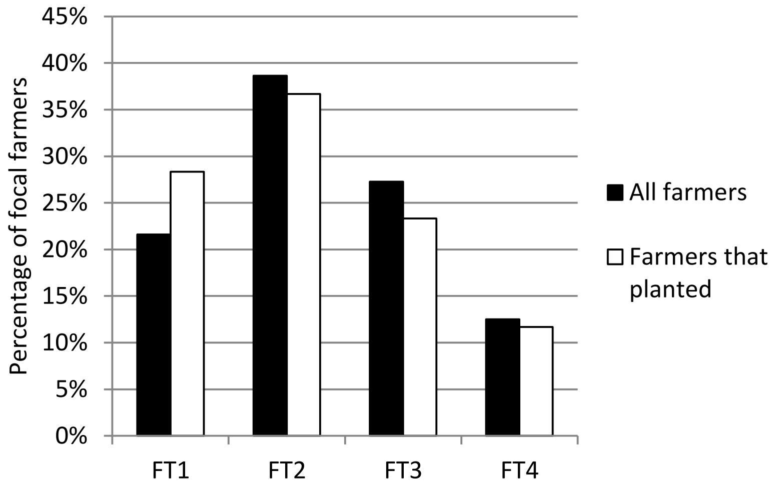

Figure 7. Distribution of focal farmers over the four farm types for all farmers (n=88) and the farmers who planted (n=60).

Table 5. Characteristics of the four farm types found in Kapchorwa district. Values between brackets show minimum and maximum values (n=88)

	Characteristics		Farm type 1	Farm type 2	Farm Type 3	Farm type 4
	n	p-value	19	34	24	11
Resource endowment	Average farm size (ha) *	-	0.3 (0.1-0.5)	0.9 (0.2-1.6)	1.3 (0.4-2.8)	2.8 (0.2-8.1)
	Tropical Livestock Unit (TLU) *	-	0.78 (0.00-2.15)	1.66 (0.01-5.33)	2.96 (1.46-5.70)	5.31 (1.41-14.95)
	Cattle *	-	0.84 (0-3)	1.94 (0-7)	3.67 (1-7)	6.18 (2-18)
	Type of housing *	-	Part semi-permanent walls with a thatched roof, part semi-permanent walls with an iron sheet roof	Mostly semi-permanent walls with an iron sheet roof, some with a thatched roof	Mostly semi-permanent walls with an iron sheet roof, some permanent walls with an iron sheet roof	Mostly permanent walls with an iron sheet roof, part semi-permanent walls with an iron sheet roof, some permanent walls with a tiled roof
	Households hiring labour during the season	<0.001	5%	25%	38%	61%
Household characteristics	Average age head of the household	0.415	42 (24-75)	47 (24-87)	46 (30-76)	48 (32-60)
	Average number of household members	0.077	8 (2-11)	8 (4-12)	7 (2-13)	6 (1-17)
	Level of education head of the household	-	Most (post) secondary, part primary, some no education	Most (post) secondary, part primary, some no education	Most (post) secondary, part primary, some no education, some university	Most (post) secondary, part primary, part university
Product orientation	Production orientation *	-	Most consumed at home, part sold	Part consumed at home, part sold	Part sold, part consumed at home	Most sold
	Most important source of income *	-	Labour in agriculture, produce from crops or some produce from livestock	Most produce from crops, some produce from livestock, some other sources of income (0-20%)	Most produce from crops, some from livestock, part off farm income (0-40%)	Most produce from crops, part off farm income (0-40%)
	Seasons planted climbing beans before	0.451	4.74 (0-20)	3.94 (0-20)	2.96 (0-20)	2.09 (0-10)
	Previous participation in the N2Africa project	0.062	11%	24%	46%	36%

* Characteristics used for creating farm types. Therefore no p-value is given.

Farmers of FT1 had smaller farm sizes than the other farm types, less Tropical Livestock Units (TLU) and cattle, poorer housing and a production orientation mainly focused on feeding the household. FT1 was the only farm type where farmers worked as labourers on other farmers' fields (Table 5). Farmers belonging to FT2 were still poor farmers, but had, on average, larger farm sizes and TLU, and an income mostly coming from crops or livestock. Farmers from farm type 3 (FT3) had even bigger farm sizes and higher TLU's, and were mostly focused on crop or livestock production for sale. Their housing was better and they hired more labourers. FT4 represents the better-off farmers, who mostly focused on selling farm produce, had the best housing, the biggest farm sizes, the highest TLU's, and hired the most labourers.

3.4.2 Geographical location

Differences in geographical location were expected to influence the implementation or adaptation of management practices as well. The sub-counties Kapchesombe and Chema/Tegeres Upper were positioned above the altitude level of 1900m, Kaptanya and Chema/Tegeres Lower sub-counties below. Each sub-county had different field officers. Accessibility of the area also differed. Furthermore, sub-counties differed in the amount of TLU they possessed, the degree of labour they hired and the number of seasons they planted climbing beans before (Table 6). Although the project was first implemented in Kapchesombe and Kaptanya, and only later in Chema and Tegeres, focal farmers from Kapchesombe (33%) and Chema/Tegeres Upper (42%) participated in an earlier season within the project. Furthermore, climbing beans were cultivated for a longer period in Chema and Tegeres, because they were introduced earlier.

Table 6. Characteristics of the four sub-counties in Kapchorwa district. Values between brackets show minimum and maximum values (n=88).

	Characteristics		Kapchesombe	Kaptanya	Chema/Tegeres Upper	Chema/Tegeres Lower
	n	p-value	21	22	19	26
Resource endowment	Average farm size (ha)	0.061	1.4 (0.2-4.6)	1.4 (0.2-8.1)	0.6 (0.1-1.6)	1.0 (0.2-2.8)
	Tropical Livestock Unit (TLU)	0.044	3.37 (0.14-14.55)	2.56 (0.02-14.95)	1.46 (0.01-4.40)	1.77 (0.00-5.70)
	Cattle	0.052	4.05 (0-17)	2.96 (0-18)	1.79 (0-6)	2.08 (0-7)
	Type of housing	-	Mostly semi-permanent walls with an iron sheet roof, part permanent walls with an iron sheet roof, some semi-permanent walls with a thatched roof	Mostly semi-permanent walls with an iron sheet roof, part with a thatched roof, part permanent walls with an iron sheet roof, some with a tiled roof	Mostly semi-permanent walls with an iron sheet roof some with a thatched roof	Mostly semi-permanent walls with an iron sheet roof, some with a thatched roof, some permanent walls with a tiled roof
	Households hiring labour during the season	0.004	41%	38%	11%	24%
Production orientation	Production orientation	-	Most sold, part consumed at home	Part sold, part consumed at home	Part consumed at home, part sold	Part consumed at home, part sold
	Most important source of income	-	Mostly produce from crops, some other sources of income (0-10%)	Mostly produce from crops, some labour in agriculture, some off farm income (0-40%)	Most produce from crops, part from livestock, some labour in agriculture, some off farm income (0-20%)	Mostly produce from crops, some off farm income (0-20%)
	Seasons planted climbing beans before	<0.001	1.95 (0-10)	0.55 (0-3)	8.94 (0-20)	3.89 (0-14)
Location properties	Previous participation (% of farmers in sub-county)	0.340	33%	23%	42%	19%
	Visited demonstration trial	0.513	67%	91%	79%	70%
	Altitude level (meters above sea level)	-	2039 (2004-2104)	1810 (1715-1882)	2000 (1906-2025)	1796 (1721-1870)

3.4.3 Distribution of farm types over sub-counties

The distribution of farm types over the different sub-counties shows that Kapchesombe sub-county is the sub-county where more than 50% of the farmers are better off (FT3 and FT4), while in Chema/Tegeres Upper sub-county almost 80% of the farmers are poor (FT1 and FT2) (Figure 8). This is mainly determined by differences in farm size, TLU and how often farmers hired labour.

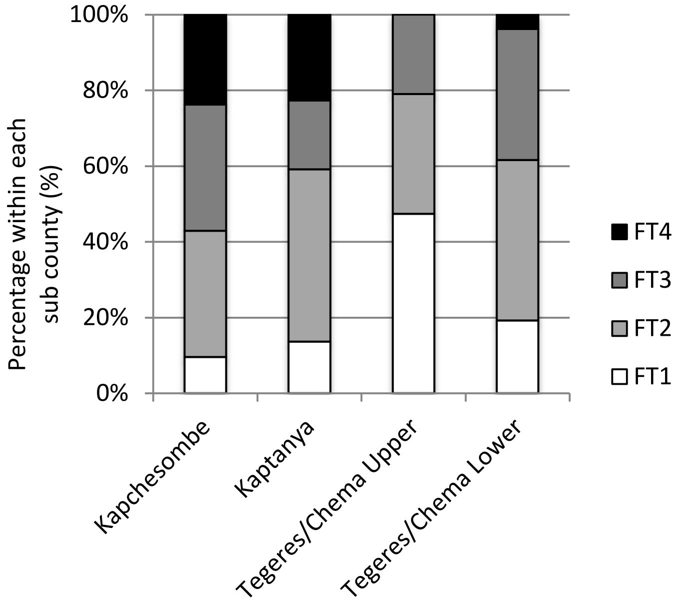

Figure 8. Distribution of farm types (FT1-FT4) within each sub county (n=88)

3.4.4 Determinants for implementation or adaptation of best management practices

Due to the differences in characteristics between farm types, we expected differences in the degree of implementation and adaptation of the best management practices. The percentage of farmers implementing certain practices differed between farm types, but none of these differences was significant (Table 7).

Table 7. Percentage of farmers implementing best management practices per farm type (n=60). For the implementation of TSP n=56, because only 56 farmers received TSP in their package. P-values are given for the mean differences of implementation over farm types.

	Best management practice from researcher best-bet	*p*-values	FT 1 n=17	FT 2 n=22	FT 3 n=14	FT 4 n=7
1	Sole cropping	0.502	18%	23%	36%	43%
2	Row planting	0.056	41%	73%	71%	29%
3	Phosphate fertilizer use (n=56)	0.676	94%	82%	86%	100%
4	Manure application	0.435	12%	14%	21%	0%
5	2 Weeding’s	0.802	12%	18%	7%	14%
6	2 Seeds per hole	0.782	35%	36%	21%	29%
7	Sowing density (320-480 plants per 5x5m)	0.236	6%	14%	29%	0%
8	Stake density (80-120 stakes per 5x5m)	0.397	24%	23%	7%	0%
9	Stakes longer than 1.75m	0.073	47%	41%	36%	43%

Similarly, also differences were expected in the degree of implementation and adaptation of best management practices between the sub-counties. From the demonstrated practices, only the percentage of farmers implementing sole cropping differed significantly between the sub-counties (Table 8).

Table 8. Percentage of farmers that implemented best management practices per sub-county (n=60). For the implementation of TSP n=56, because only 56 farmers received TSP in their package. Letters indicate significant differences. *P*-values are given for the mean differences in implementation between de sub-counties. T/C = Tegeres and Chema sub-county.

	Best management practice from researcher best-bet	*p*-values	Kapchesombe (n=15)	Kaptanya (n=11)	T/C Upper (n=14)	T/C Lower (n=20)
1	Sole cropping	0.033	53% (a)	18% (ab)	7% (b)	25% (ab)
2	Row planting	0.905	53%	55%	57%	65%
3	Phosphate fertilizer use (n=56)	0.532	80%	100%	93%	85%
4	Manure application	0.220	27%	0%	7%	15%
5	2 Weeding's	0.326	7%	9%	7%	25%
6	2 Seeds per hole	0.111	13%	45%	43%	30%
7	Sowing density (320-480 plants per 5x5m)	0.080	20%	0%	0%	25%
8	Stake density (80-120 stakes per 5x5m)	0.843	13%	9%	21%	20%
9	Stakes longer than 1.75m	0.237	33%	27%	36%	60%

In the remainder of this section we explore the determinants for the nine best management practice in more detail.

Sole cropping (1)

Farmers from Kapchesombe made significantly more use of sole cropping than farmers from T/C Upper (Table 8). Of the farmers who practiced intercropping, 25% participated in the project during a previous season, and of the farmers who did sole cropping, 63% did. This difference was also significant (*p*=0.031). When the two altitude levels are taken (the first level being below 1900m, the second level being 1900m or higher) an almost significant difference is found (*p*=0.082), showing that in the lower region, 17% of the farmers practiced sole cropping whereas in the higher region, this amounted to 37%.
The number of seasons farmers had already planted climbing beans before did not influence the choice between sole cropping or intercropping (*p*=0.800). Although farmers from FT1 mostly planted climbing beans in intercropping, and farmers from FT4 mostly in sole cropping (Table 7), there is no significant difference between farm types. Furthermore, we tested the relation between sole cropping and farm size. Farmers who planted in sole cropping had an average of 2.6 ha and farmers who planted in intercropping an average of 2.1 ha. However, this difference was not significant (*P*=0.275). Sole cropping is therefore only determined by sub-county and previous participation in the project.

Row planting (2)

Farmers planted the beans either in rows or randomly (i.e. without a fixed distance between plants). Differences between farm types were almost significant (*p*=0.056): farmers from FT1 and FT4 more often planted beans randomly (Table 7). Differences in percentage of row planting implemented by farmers who hired labour permanently, regularly, sometimes or never, were not significant (*p*=0.795). From the farmers who planted in rows, 71% visited the demonstration trials. Among the farmers who planted randomly this was 80%. This difference was not significant (*p*=0.552). Furthermore, there was no difference in the number of seasons that farmers already planted climbing beans before when they planted in rows (5.49) or randomly (4.64) (*p*=0.683). Lastly, 62% of the farmers who participated in the project during a previous season planted in rows, as well as 56% of the farmers who had never joined this project before, which also did not present a significant difference (*p*=0.687). For row planting, only farm types were found to be possible determinants.

Phosphate fertilizer use (3)

Four farmers received a package without TSP. Two of them visited the demonstrations (4% of the total number of farmers who visited the demonstration trial), and two of them did not (13% of the total number of farmers who did not visit the demonstrations trial). Of the farmers who did not visit the demonstration and received TSP (n=13), 77% planted with the TSP, while from the farmers who were present in the demonstration trials and received TSP (n=43), 98% planted with TSP. This difference was significant (*p*=0.035).

Of the farmers who previously participated in this project and received TSP, 100% planted with fertilizer, compared to 89% of the farmers who participated for the first time. This difference was not significant (*p*=0.285). There was furthermore no significant difference in TSP application between farm types (Table 7), or between sub-counties (Table 8), probably because TSP was part of the distributed package and did not have to be bought.

Manure application (4)

The percentage of farmers who applied manure was not significantly different between the different farm types (Table 7). Still, a relation was expected between cattle ownership and the application of manure on the adaptation trial plot. However, the number of farmers who owned cattle and applied manure (16%) did not significantly differ from farmers who did not own cattle and still applied manure (7%) (*p*=0.666).

Farmers with more cattle have significantly more land ($p < 0.001$, $R^2 = 0.305$, Figure 9). This relation could be an indication of wealth in general, and therefore the relation between manure application and farm size was also tested. Farmers who applied manure have an average farm size of 0.68 hectares, and farmers who did not apply manure have an average farm size of 1.18 hectares, but this difference was not significant (*p*=0.299). This outcome is nonetheless not what was expected and counterintuitive in relation to wealth.

Another possible reason for applying manure less often could be land ownership. Farmers who do not own the land where the beans are planted also have less incentive to invest in the land. However, farmers who rented or borrowed the land applied manure more often (21%) than farmers who owned the land (11%), and this difference was also not significant (*p*=0.374).

Farmers from Kapchesombe own more livestock and more cattle than farmers from other sub counties (Table 6). Farmers from Kapchesombe also implemented manure more often than farmers from other sub-counties; but differences between sub-counties were not significant (Table 8).

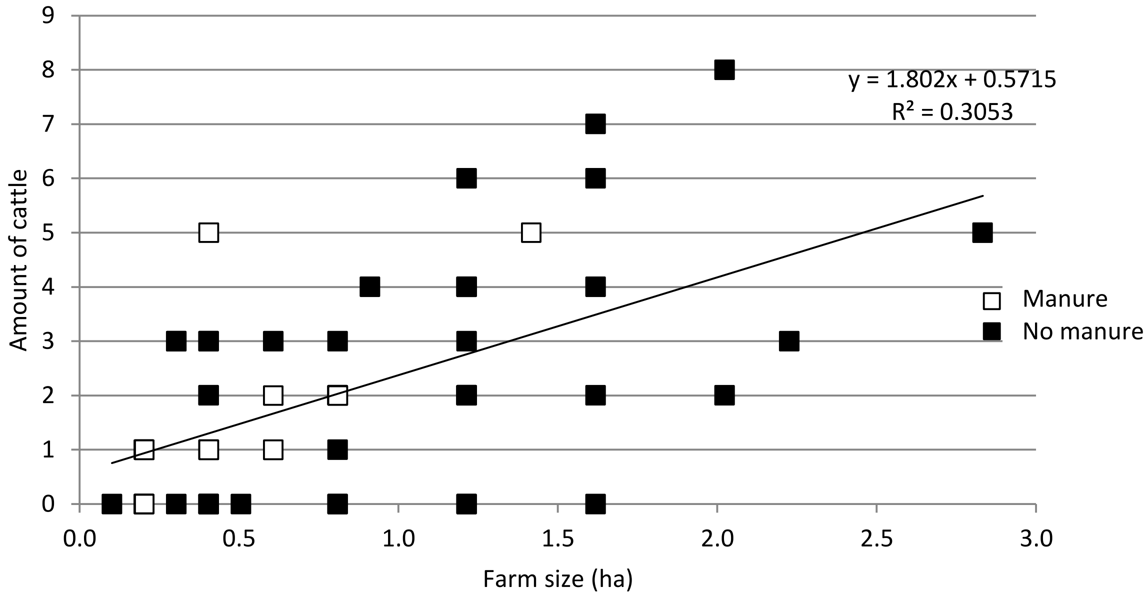

Figure 9. Farm size (ha) as related to number of cattle possessed by the farmers (n=57, p<0.001, R^2 = 0.305). White and black marks indicate manure and no-manure application, respectively.

Weeding (5)

The demonstration trials were weeded twice, but farmers were told to follow common practices regarding weeding. A negative trend can be found between the number of seasons that farmers already planted climbing beans before and the number of times farmers weeded their plots, but the difference is not significant (Figure 10).

Furthermore, there was no significant difference between sub-counties and the percentage of farmers that weeded twice (Table 8), nor was there any significant difference in the average times farmers weeded (*p*=0.488). The number of weedings was not related to farm type either (*p*=0.885), nor was there a significant difference between farm types and the percentage of farmers that weeded twice (Table 7). The hiring of labourers also did not seem to influence the amount of weedings: those that hired labour permanently (n=3) weeded 0.67 times, those who did so regularly (n=9) weeded 0.67 times, those who did so sometimes (n=19) weeded 0.79 times, and those who never hired labourers (n=29) weeded 0.93 times (*p*=0.652).

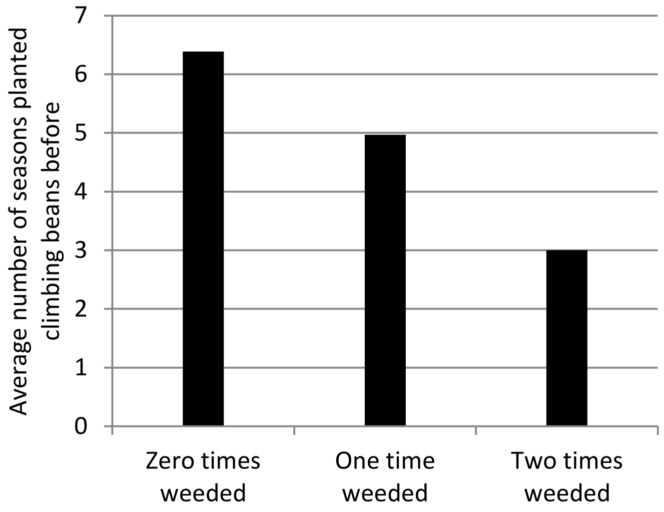

Figure 10. Frequency of weeding versus the average number of seasons that farmers planted climbing beans before (p=0.308).

Seeds planted per hole (6) and sowing densities (7)

Farmers with less financial resilience are more risk-averse and need to be sure they produce food crops every season to be self-sufficient (Nyende & Delve, 2004). Farmers from poorer farm types were therefore expected to have a production orientation focused on home consumption. Furthermore, because they also have smaller farm sizes, they were expected to plant a larger number of seeds per hole, to account for potential losses related with seed quality or poor emergence. However, differences between farm types concerning the number of seeds planted are not significant (p=0.301). There was no significant difference between sowing densities used either (p=0.236). Visiting the demo also did not influence the difference between the number of seeds planted per hole in any significant way, because whether farmers visited the demo or not, they planted an average of 3.06 seeds per hole (p=1.000). Farmers who had visited the demo had a sowing density of 287 seeds per 25m^2; those who did not visited sowed 306 seeds per 25m^2 on average – a difference which was, once again, not significant (p=0.787).

Stake density (8)

Farmers were asked to score the availability of stakes on a scale from 1 to 4, with 1 being very poor and 4 being good. On average, farmers from Kaptanya gave a higher score to the availability of stakes than farmers from the other sub-counties (Figure 11A). However, while farmers from Kaptanya gave the highest score for staking availability, they had, on average, the lowest staking density (Figure 11B). Nonetheless, the differences between staking densities were not significant. Stake densities between the subcounties in the higher altitudes (64 stakes per 5x5m) and the subcounties in the lower altitudes (56 stakes per 5x5m) is also not significantly different (p=0.341).

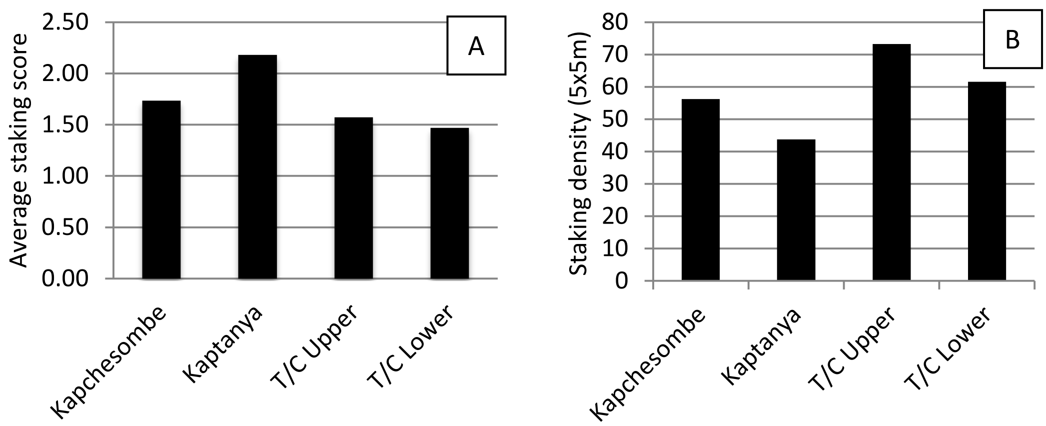

Figure 11 A. Average score for staking availability per sub county (n=60). 1=very poor, 2=poor, 3=average, 4=good, 5=very good. B. The average staking density in an area of 5x5 meters seen per sub-county, for farmers who staked (n=56) (*p*=0.170). T/C = Tegeres and Chema sub-county.).

Stake length (9)

Farmers from sub-counties located above 1900m asl live closer to the forest and were expected to have better access to staking material. With an average stake length of 187 cm in the sub-counties below 1900m asl and 163 cm in the sub-counties above 1900m asl, differences in average staking length are almost significant (*p*=0.056). This is remarkable, since the average stake length of the sub-counties in the higher altitudes was expected to be higher than the average stake length of the lower sub-counties. Finally, if farmers participated in the project during an earlier season they had, on average, stakes of 177cm; if not, the average stake length was 173cm, which was not a significant difference (*p*=0.752).

In summary, we only found a few determinants and possible determinants (with p-values lower than 0.1) for the implementation of the nine best management practices. (Table 9).

Table 9. Summary of (possible) determinants for the nine best management practices.

	Best management practice from researcher best-bet	Determinant (p<0.05)	Possible determinant (p<0.1)
1	Sole cropping	Farm size, earlier participation in project	Altitude
2	Row planting	-	Farm types
3	Phosphate fertilizer use	Did not visit demonstration	-
4	Manure application	-	-
5	Weeding's	-	-
6	Number of seeds per hole	-	-
7	Sowing density	-	-
8	Stake density	-	-
9	Stake length	-	Altitude

3.5 Yield of adaptation trials

Climbing bean yields for farmers that planted in two plots and from which harvest was measured from both plots (n=8) showed no significant differences in yields with and without TSP (*p*=0.651)

(**Error! Not a valid bookmark self-reference.**). Yields also did not differ significantly between different sub-counties (*p*=0.511), or farm types (*p*=0.125).

Table 10. Average climbing bean yield (kg ha^{-1}) for farmers with two plots, all farmers that planted, farmers from different sub counties and farmers from different farm types.

		n	Average yield (kg/hectare)
Farmers with two plots	Plot with TSP	8	224.0
	Control plot	8	206.4
All farmers	Plot with TSP	19	292.9
Sub counties	Kapchesombe	6	379.4
	Kaptanya	4	143.6
	Chema/Tegeres Lower	9	284.9
Farm types	FT1	6	216.8
	FT2	5	170.3
	FT3	5	540.1
	FT4	3	209.4
Demonstration	Instructions	-	-

Although farmers received the same amount of TSP, farmers had planted different plot sizes and therefore applied different amounts of TSP per hectare. When the amount of TSP (kg) that was applied per hectare is related to yield (kg) per hectare, no trend can be observed (Figure 12). So, the same yields are achieved, while seemingly larger amounts of TSP are applied. Or when the same amount of TSP is applied, different yields are found (e.g. 60kg TSP ha^{-1}). These differences cannot be further explored, however, due to the low sample size of yields.

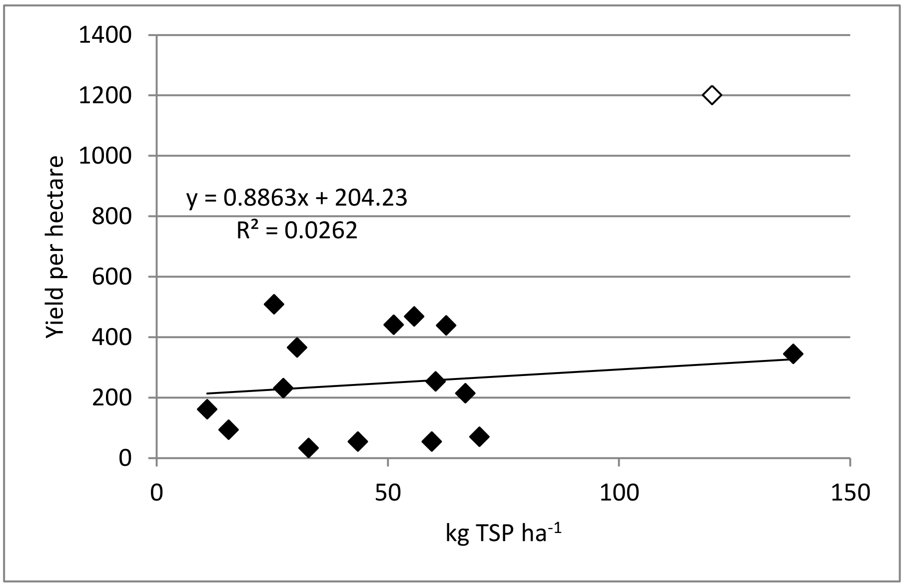

Figure 12. The amount of TSP applied per hectare as related to the yield per hectare (n=16, two farmers had missing data). The white data point is not used for the trend line.

4 Discussion

The main goals of this study were first to investigate to what extent focal farmers implemented or adapted the technology package and any of the practices demonstrated at the demonstration trials, and secondly what the determinants are for this implementation or adaptation. A third goal was to relate differences in implementation of the management practices with climbing bean yields. Below the main results are discussed, where after the last goal, what lessons researchers can obtain from farmers' adaptations and how this should influence future demonstration trials and/or research questions, is answered.

4.1 Implementation, adaptation and their determinants

Implementation and adaptation in this analysis were found to be hard to disentangle. Two different examples stress this. First, if farmers did not plant the seeds, this was most of the time because they adapted to the emerged situation. Farmers received the seeds late and decided to wait with planting the seeds, because weather conditions changed and became more unpredictable or their fields were already occupied with other crops. The second example is because sole cropping is a best management practice shown in the demonstration trial, but most farmers planted in intercropping, making it an adaptation to sole cropping. Therefore, implementation and adaptation are discussed together, because they are two sides of the same coin.

4.1.1 The technology package

Farmers had several reasons to decide not to plant, and to explain the low yields they obtained: pests and diseases, changing weather conditions, lack of space, and the late distribution of seeds. Despite the fact that pests, diseases and changing weather conditions are difficult to tackle due to their unpredictability (Karanja et al., 2011; Wortmann et al., 1998), they can be better dealt with when seeds are disseminated in time. For all stakeholders within the project, early dissemination of seeds is therefore very important. Furthermore, in this way problems with loose chickens damaging the emerging beans can also be overcome, because farmers tie their chickens when they are collectively planting.

Only a small part of the farmers who planted the beans ended up having yield. Moreover, measured yields were much lower than potential yields. All yields measured were below 600kg per hectare: farmers who planted their beans with TSP had an average yield of less than 300kg per hectare. This is far below the potential yield of 3.5 to 5.0 ton per hectare (Musoni et al., 2014). Although lower yields are to be expected on-farm, compared to yields realized in research stations (Dusabumuremyi et al., 2014), the exact reason for low on-farm yield compared to potential yield is difficult to pinpoint (Douthwaite et al., 2002). The low yields and differences in yields in this research are likely to be influenced by weather conditions, variability in initial soil fertility, or management practices like sowing densities or weeding. Next to this, the final sample size of yields that are measured was too small for doing the right analyses.

Furthermore, only a small part of the farmers planted in two plots, and even those who did so often did not do this deliberately. Since farmers also did not clearly mark their two plots and had very diverse reasons for not planting two plots, analysis of yields between the control plot and the plot with TSP became more difficult and unreliable. Recommendations from Douthwaite et al. (2002) suggest that placing restrictions on adaptation trials to measure the yields from two different plots, can constrain farmers' learning cycles, and farmers need to be provided with technologies that are straight forward: easy to understand and easy to modify. In the first season of 2015, farmers were therefore provided with a package with seeds and fertilizer, without further restricting them with a 'standard fixed control', as proposed in the Agronomy Master plan (Vanlauwe et al., 2014). As an alternative for the control plot of the focal farmers, the project now uses the farmers' current climbing bean practice as a control.

4.1.2 Intercropping and row planting

Farmers who participated in an earlier season in the project planted more often in sole cropping than in intercropping, which might be a continuous implementation of the previous season. However, this can only be verified if these farmers are followed for more seasons. Still, most farmers planted in intercropping. Sole cropping of climbing beans can give higher yields when management conditions are right (Fujita et al., 1992; Graham & Ranalli, 1997), but is according to literature not specifically the option more preferred by farmers (Van Damme et al., 2014). Advantages associated with intercropping include more efficient use of the growing season, risk avoidance, diversity in products, protecting the soil from erosion and control pests and diseases and control weeds through shading effects (Giller et al., 2015; Karanja et al., 2011; Ojiem et al., 2006). Most farmers in Kapchorwa intercropped the beans with banana and coffee, of which coffee is only used in the Eastern part of Uganda to intercrop with beans (Farrow, 2014). Therefore, not much quantitative research is done on the intercropping of beans with coffee or banana. Because many farmers in Kapchorwa intercrop the beans with coffee or banana, this is something that could be examined more in future research.

Random planting is less labour demanding at planting and poor farmers normally choose for options that lower the amount of labour that is needed (Vandeplas et al., 2010). This might explain why poorer farmers plant less in rows, although it can work counter-productive in the end, when it gets harder to weed and stake if the beans are planted randomly. Furthermore, the more wealthier farmers also planted less in rows. A possible reason for this might be the lack of interest of these farmers in crops that have no good perspective for sale, because of the low quantities that can be produced with the distributed seeds or because of the poor market access for sale. Furthermore, if farmers planted in rows, this was not influenced by de amount of labour farmers hired.

Nonetheless, narrow row planting is associated with higher yields and less pests (Adipala et al., 2000; Dusabumuremyi et al., 2014). An option for the project could be to show the difference between wide and narrow row planting for the farmers to see the effect of different row distances on yield and pest control.

4.1.3 Mineral and organic fertilizer

A smaller percentage of farmers who were not present at the demonstrations trials planted with TSP than farmers who did visit the demonstration trials. Although this was the only practice that was determined by a visit to the demonstration, good extension services are necessary for a project to work well. Extension officers provide different information and controlling for these differences in information, is only possible if the technology is very narrowly defined (Aker, 2011). Because the extension officers were not systemically monitored, they could influence the outcome of the implementation and adaptation of the best management practices, because they work in different geographical locations, at different moments and with different incentives. The performance of a project in different locations is therefore even more difficult to compare. Differences between extension officers should therefore be part of the monitoring of the project.

Although not significant, farmers with cattle applied more often manure on their beans, than farmers who did not own cattle, which was also the case in Kapchesombe, where the most cattle was available and the most often manure was applied. Therefore, a trend can be seen between farmers who own cattle and the farmers who apply manure: farmers with cattle apply more often manure, something which is also seen in other research (Okoboi & Barungi, 2012; Tittonell et al., 2005). However, farmers who applied manure had smaller farm sizes than farmers who did not apply manure. Farmers with smaller farm sizes can perhaps more easily use manure on the small (number of) fields that they have, whereas farmers with larger farms may only apply manure on a small portion of their farm close to the homestead. Because applying manure is labour intensive (Okoboi & Barungi, 2012) and even more when the fields are further away from where the manure is, this might also explain why farmers with larger farm sizes apply less manure. In general, the use of manure was very low. Farmers do not only use manure to increase yield or improve soil fertility, but use it also as construction material for their houses or fuel (Karanja et al., 2011). This further limits the availability of manure as organic fertilizer.

The few farmers who did not use TSP because they did not receive fertilizers from the project gave the reason they had no means to buy fertilizers. This gives a small insight in what might happen when there is no project that supplies fertilizers; farmers are likely to plant the beans without fertilizer. Other studies give several reasons why the application of fertilizers by smallholder farmers is limited: unaffordable prices, low quality of mineral fertilizers or a lack of local infrastructure (Karanja et al., 2011; Pircher et al., 2013). If farmers use manure or mineral fertilizers, this is most often applied on high-value crops like maize or bananas.

Because farmers use manure for different purposes and because the use of mineral fertilizers is limited, the project could focus on the more efficient use of manure and mineral fertilizers in intercropping systems of beans with high-value crops or focus on other low-cost external inputs like crop residues of coffee and banana or stimulate to incorporate climbing bean biomass into the soil.

4.1.4 Staking

Farmers mostly used single staking: the method they also used for their local climbing beans and which yields most (Descheemaeker et al., n.d.). Some of the farmers also used tripods to stake their beans, but this was only to strengthen or support their single stakes. Tripods were intended to enhance yields as stakes would not easily fall over, but were also expected to be more labour intensive and therefore to be used mostly by wealthier farmers. However, tripods were not necessarily used by wealthier farmers, and were only used to support weaker stakes for those who did not have enough stakes. Sisal strings were intended to provide a low-cost alternative for single stakes in an area like Kapchorwa where farmers mention staking as a major constraint for climbing bean cultivation. Still, in the adaptation trials none of the farmers used this option. The explanation is probably three-fold. First, labour and material costs: single stakes seemed to be easier to find and to plant than the eucalyptus poles that could hold the strings. In addition, attaching the strings and fibres to the poles took a lot time and effort. Second, the robustness of the strings: when placed in an open area or field, the wind could get hold of the strings and the beans could be moving from one side to the other. This most probably will result in damage to the beans, either during growth or during maturing stage, when flowers are vulnerable. Thirdly, not only were the beans of the farmers staked late, beans in the demonstration fields were also supported very late and not at the same time. Midway October, most sisal strings and banana fibres were not yet attached to the poles on all the demonstration sites. Focal farmers were already staking before the beans were staked in the demonstration trials. This influenced the outcome of the implementation, because the only staking methods farmers were already familiar with and which they mostly implemented, was single staking. Therefore there was never an equal race between the displayed methods of staking. During planting, farmers were told to stake early after three leaves emerged. However, this was not done in time in the demo plot, which did not give a good example. This reflects however also the difficulty in a project like N2Africa of getting the right materials together to be implemented in the field.

In the demonstration trials mostly bamboo was used as staking material. The focal farmers, however, never used bamboo to stake the beans. Farmers used local trees and shrubs for staking, that were

also used as firewood or as construction material and which caused problems with theft and shortness of firewood. This reflects on a problem for both the farmers as well as for the project. While the project aims to show different staking methods in a uniform way, it does not reflect the staking materials used in farmers' fields. Because the availability of staking material is still a problem for many farmers, the N2Africa project intended to collaborate with the Ugandan agricultural organisations NARO and VECO, to create nursing beds for local and fast growing trees for staking. These beds were however never implemented in this region. Since nursing beds are still much needed in the region, collaboration with these organisations should be renewed or other stakeholders should be engaged in the project. Especially since although farmers mentioned they got stakes from around their farm, this might be a cover-up story for them getting their staking material from the national forest, which is protected and therefore illegal to enter for fetching wood (Ramaekers et al., 2013). Therefore, the real source of their stakes stays uncertain and could imply hidden labour costs like the transport of stakes (NaCRRI et al., 2012).
During the season (2014b), maize stalks from an earlier season were also used as staking material in the demonstration trials. This is a solution used more often in the past (Niringiye et al., 2005; Odendo et al., 2011), but feedback from the focal farmers on this technology was not systemically recorded, which gives an important gap that can be filled by future monitoring.

Stake density was lower in the adaptation trials compared to the demonstration trials and many plants in the field were still not staked at all. This together resulted in low amounts of plants per stake. The sub-counties in the higher altitudes were expected to have higher staking densities and longer stakes due to the proximity to the forest. Although not significant: stake densities were indeed slightly higher. Average stake length, however, was almost significantly lower. There is no obvious reason for this relation.

And although not significantly different, the lowest staking density was found in Kaptanya, while farmers in this sub-county gave the highest score for staking availability. This suggest the availability of bushes or other materials for staking is relatively good, but farmers are less willing to stake in higher densities. Lower yields are expected due to unstaked climbing beans, although they can still perform better than some of the best performing bush beans (Musoni et al., 2014), which might makes it a yield loss for farmers in Kaptanya.

4.1.5 Project practicalities

From the beginning it was unclear, which farmers were present during planting of the demonstration trials, when instructions were given. Lists of farmers who were present at the demonstration trial were available, but many of the farmers on the list never received a package or were even not present at the demonstration trials. Therefore, from the lists it was impossible to exactly say which knowledge the farmers really received, or if they even received the package and what part of the package they received. Therefore, by keeping records of which farmers received the package, which farmers were present during the demonstrations, and which practices are demonstrated, the analyses on adaptation and implementation can be better related to the demonstrated practices. In this way best management practices can be better adjusted to the local realities of farmers.

Farmers in the upper part of Chema/Tegeres were provided less with packages with seeds, fertilizers and a leaflet compared to the farmers in the lower areas of these sub-counties. The extension officer explained this by attributing it to the low interest from farmers in the upper areas and the farmers being busier with drinking alcohol than with farming. However, it was also part of the lack of interest of the extension officer himself. When he had seeds left after the demonstrations, he disseminated them to farmers close to the main road in the lower areas, close to his own house. This again pleads for better monitoring of extension officers.

Initially the same amount of farmers per sub-county was selected for conducting the surveys. By doing so, the amount of farmers in each farm type was uneven and therefore statistical analyses on farm types became hard. For future research to be able to say more about farm types being responsible for the implementation or adaptation of best management practices, sampling should also be stratified according to farm types. This could be done by a quick farm typology of farmers in the area, focused only on the factors that are used for grouping farmers in different farm types. After this a more balanced sample could be taken for further analyses with farm types as determinant.

4.2 Lessons learned and future research

From the results of this study, we can draw a number of lessons that could inform the future implementation of the N2Africa project, as well as future research:

- Seeds should be disseminated in time for the project to be able to have impact. Adaptation trial farmers should not be restricted in the way they are to plant the beans.
- Adaptation trial farmers might implement sole cropping more in the future, because farmers who participated before in the project planted more in sole cropping. However, most farmers in Kapchorwa district planted the climbing beans in intercropping with mostly banana and coffee and therefore more research could be done on the intercropping of these particular crops with climbing beans.
- Poorer and wealthier farmers planted more in random planting, which saves labour during planting. Future research could further explore if these two groups of farmers always choose the short-term orientated labour saving option. By knowing this, these specific groups can be targeted with management practices that fit better to their needs. Furthermore, the effect of row and random planting could be shown in the demonstration trials for farmers to experience the impact this has on crop performance.
- Differences between extension officers could be monitored better, to allow an improved comparison of the performance of the project in different locations.
- Farmers with cattle have manure available and farmers with small farm sizes apply more often manure than farmers with larger farm sizes. If future research shows this is true, farmers with larger farm sizes (most often the wealthier ones) can be targeted with other soil improving measurements.
- If the project leaves the area, farmers are also less likely to use mineral fertilizer. Therefore the use of mineral fertilizers in intercropping systems could be promoted more, to make more efficient use of the applied mineral fertilizer on high-value crops. Furthermore, other low-cost alternatives such as the implementation of compost or incorporation of crop residues of banana or coffee in the soil could be promoted.
- The beans in the demonstration trials were not all staked at the same moment and the alternative staking method was not implemented in time. This not only influenced the performance of the beans, but also the implementation of these alternative-staking methods by the focal farmers.
- Staking availability is still poor in the area and the need for nursing beds for new staking materials is present. Furthermore, the option to use maize stalks from the previous season could be better monitored, since also focal farmers used this method and during this research it was not enough explored.
- Better records could be kept of the farmers who received a package and who were present during demonstrations. In this way implementation and adaptation of (best) management practices could be better related to demonstrated practices.

5 Conclusions

From the discussion of the content of this study, and the way the study was executed, we can draw a number of final conclusions on the project set-up, possible future research and advices on best management practices and finally on the research set-up.

5.1 Project set-up

Extension workers in different locations do not perform the same; by giving different instructions, different varieties of seeds or giving only part of the package to adaptation farmers, adaptation farmers are beginning from a different starting point . During instructions at the demonstration trials, farmers have to be monitored and registered better, for extensions workers and researchers to know better if farmers were present during the instructions, and which practices were discussed and demonstrated.

To give farmers the opportunity to plant the beans in their preferred fields, at the time that they consider to be best, seeds should be distributed in time. This means before farmers start planting other crops and vast in time before the season starts. Furthermore, the project could give farmers a technology package, but without instructing them to plant in two plots or give them any other planting restrictions in general.

5.2 Possible research and advice on best management practices

To translate 'best-bet' management practices into more locally relevant options, more research could be done on the intercropping of beans with coffee and/or banana. This intercropping system is often used in Kapchorwa district, but not much research is done on the benefits and trade-offs of the system.

Poor staking availability is an issue in the research area. The use of maize stalks in the demonstration trials and in the focal farmers field should be monitored better in the future, because this might be a good alternative to wooden stakes. Furthermore, nursing beds for local and fast growing trees for staking should be created in the area, to meet the local demand of staking materials.

Few farmers used manure in the adaptation trials. Farmers with cattle have manure available, but they are likely to also use it for different purposes. The small number of farmers that bought (additional) mineral fertilizer, of which none was TSP, indicates that if the project leaves the area, farmers are also less likely to use mineral fertilizer. Therefore, the project could focus on the more efficient use of manure and mineral fertilizers in intercropping systems of beans with high-value crops or focus on other low-cost external inputs like crop residues of coffee, banana and climbing bean.

5.3 Research set-up

The relatively small sample size in this study, limited many of the analyses. To be able to draw more meaningful conclusions (on e.g. farm types and yields), a larger sample size is needed.

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Appendix I Demonstration of climbing bean technology options in Kapchora

Demonstration of climbing bean technology options in Kapchorwa, Kabale and Kanungu Districts

Objectives

1. To demonstrate a range of climbing bean technology options, focusing on different varieties, inputs and staking methods.

2. To compare the performance of the technology options in terms of biomass and grain yield.

3. To evaluate the impact of biophysical conditions on the performance of the technology options.

Sites

The demonstrations will be established Kapchesombe, Kaptanya, Chema and Tegeres sub-counties in Kapchorwa district, in … sub-county in Kabale District and in Mpungu sub-county in Kanungu District. Demonstrations will be established at parish level, with a total of 15 demonstrations in Kapchorwa District, … in Kabale District and … in Kanungu District. The demonstrations will be established on-farm and will be jointly implemented and managed by researchers and farmers. The demonstrations will be hosted by a farmer who is willing to lend a sufficient amount of land for this purpose. All farmers of the parish should be invited to be present at important phases of the crop cycle (planting, staking, flowering, harvest) to receive training on agronomic aspects (NaCCRI) and marketing/ post-harvest handling (VECO/ A2N).

Treatment structures

Treatment	Crop	Variety	Cattle manure	TSP	Staking method	N° of seeds per hole	N° of plants per stake
1	Climbing bean	Local Kabale	-	-	Single stakes	2	2
2	Climbing bean	NABE 12C	-	-	Single stakes	2	2
3	Climbing bean	Local Kabale	+	-	Single stakes	2	2
4	Climbing bean	NABE 12C	+	-	Single stakes	2	2
5	Climbing bean	Local Kabale	-	+	Single stakes	2	2
6	Climbing bean	NABE 12C	-	+	Single stakes	2	2
7	Climbing bean	Local Kabale	+	+	Single stakes	2	2
8	Climbing bean	NABE 12C	+	+	Single stakes	2	2
9	Climbing bean	Local Kabale	+	+	Tripods	2	2
10	Climbing bean	Nabe 12C	+	+	Tripods	2	2
11	Climbing bean	NABE 12C	+	+	Half sisal/ half banana fibre	2	2

IN KAPCHORWA: Four demonstration sites in Chema and Tegeres sub-counties include a 10th treatment of maize stalks (planted in season 2014A) used as stakes. In this treatment: plant the beans when maize is reaching physiological maturity (black layer), or a few weeks before. Plant on the base of the maize, a few cm off, and plant alternating the rows: plant between row 1 and 2, right and left of the maize plants respectively, skip one row as alley, plant again between row 3 and 4, in the middle.

Demonstrations design

- The demonstration will be installed as one experiment with 11 plots (Figure 1).

- Plot size: 5 m long and 5 m wide = 25 m^2 per plot (Figure 1).

- Spacing beans: 50 cm between rows by 25 cm within row. Apply two seeds per hole at planting and thin to one after germination. Each plot should accommodate 10 lines (Figure 2).

- Staking: for the single stakes and tripods, choose staking material that is most commonly used by farmers in the area (e.g. Eucalyptus, bamboo, Sesbania). The sisal strings will be tied to a strong rafter (e.g. from bamboo or other locally available material) resting on two strong Y-shaped sticks (Figure 3).

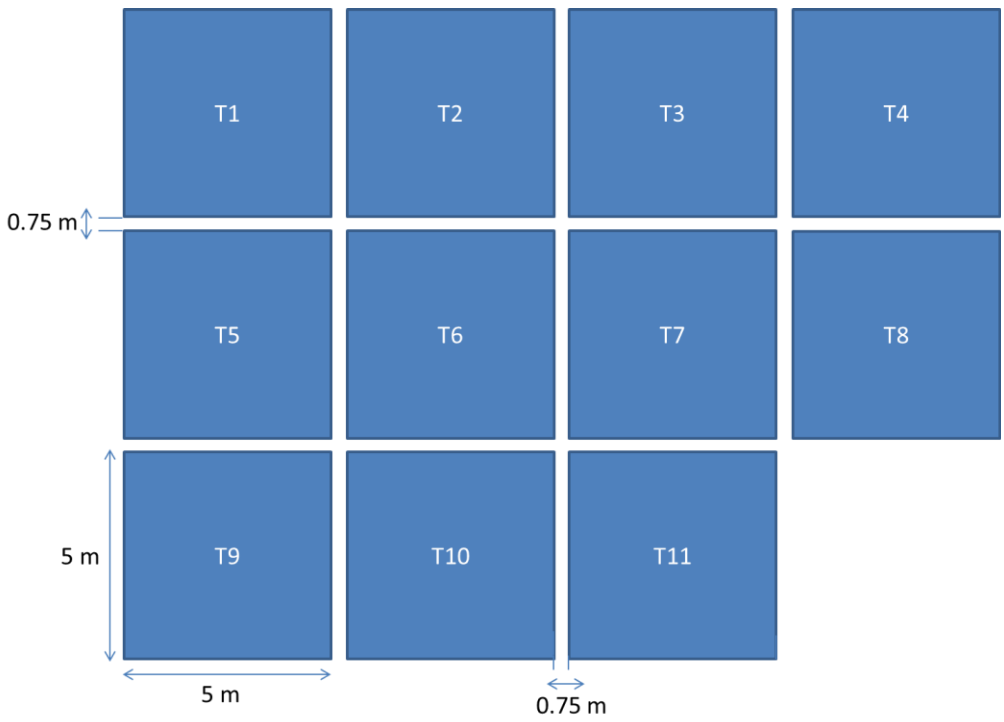


Figure 1: Sketch of the climbing bean demonstrations

Figure 2: Sketch of row and plant spacing per plot

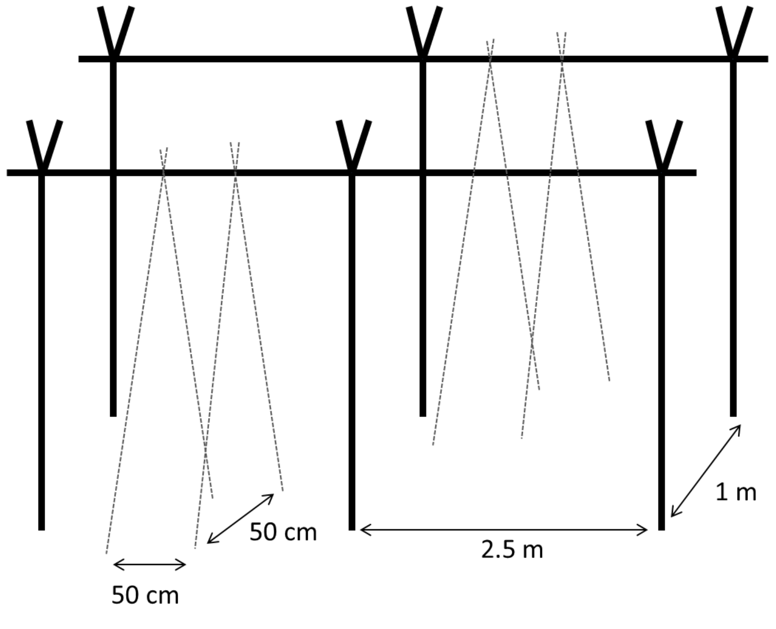


Figure 3: Sketch of banana fibre and sisal string staking method. Grey dotted lines represent the strings. The strings should be placed in between two plants within each row, so that each string holds two plants.

Site selection:

- The demonstration sites should be chosen in a strategic location, which is visible and accessible for as many people as possible (e.g. a prominent roadside location, next to a school, etc. But not too close to dusty areas).

- The trial should be laid out on an N-deficient site that is homogenous, does not have a very steep slope and no indicators for soil degradation (e.g. lots of gravel in the topsoil).

- We should also avoid areas in inland valleys with potential for water-logging.

- The approximate area needed per demonstration site is approximately 400 m^2 (23 * 17 m or 35 * 11 m).

Application of inputs

- Fertilizer rates: TSP will be applied using a rate of 15 kg P per hectare; cattle manure at a moderate rate of 2 t/ha.

- Fertilizer application: The mineral fertilizers will be banded, 10 cm away from the planting line, in a 2-cm deep trench and covered after application. Cattle manure will be broadcasted followed by shallow tillage before planting.

- Weeding: weed the demonstration according to recommended practice.

- Retain some seed to fill gaps as necessary.

Inputs needed per 25 m^2 plot

Type of input	Amount needed per 25 m^2 plot
Seed (var. NABE 12C)	0.25 kg
Seed (var. Kabale local)	0.20 kg
TSP	0.190 kg
Manure	5 kg

Farmer learning:

→ Farmer learning from the demos at relevant stages during the season should be facilitated by NARO and VECO designated staff in each area with backstopping support by a research assistant from Makerere University. A Field Day should be held to enable all farmers in the area to learn from the demonstrations.

→ NARO will use its training approach to ensure farmers' capacity is built to handle agronomy issues (planting, nutrient input application, weeding, disease and pest control).

→ VECO will use its training approach to ensure farmers' capacity is built to handle pre- and post-harvest handling (harvesting, storage management and value addition), and marketing and market linkages i.e. issues along the value chains.

Observations

A separate *Field book for demonstration trials* will be supplied where the following information should be registered during the season:

- At the front page of the data collection sheet for the demonstrations, include the name of the demonstration and the site in a unique code, for example Bean-Ug-Kan-01. Use this code also for any other observations and measurements. Each demonstration has to have a unique code!
- GPS position of the demonstration (decimal degrees)
- Initial soil sampling
- Rainfall
- Planting dates and dates of management practices
- Emergence %
- Physiological dates (days to flowering, podding, maturity)
- Pest and disease scoring
- Occurrence of severe drought, flooding or other catastrophic events

Measurements at harvest

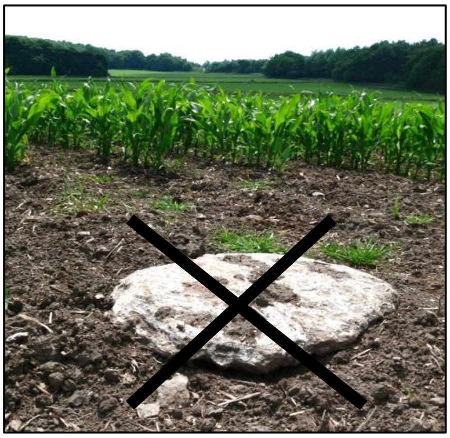
Harvesting should be done by NARO staff. It is very important to ask farmers **not to harvest** anything during the season. All legumes will be shelled on site at harvest, with the exception of groundnut. Store (shelled) grain, husks and stover in separate yield bags that are labelled with the corresponding plot numbers and treatments. Fresh weight of grain, husks and stover will measured with a precision of two decimals with a digital hanging scale (to be provided).

Appendix II Instructions for planting and harvesting

Instructions for planting and harvesting

1. Selecting the land

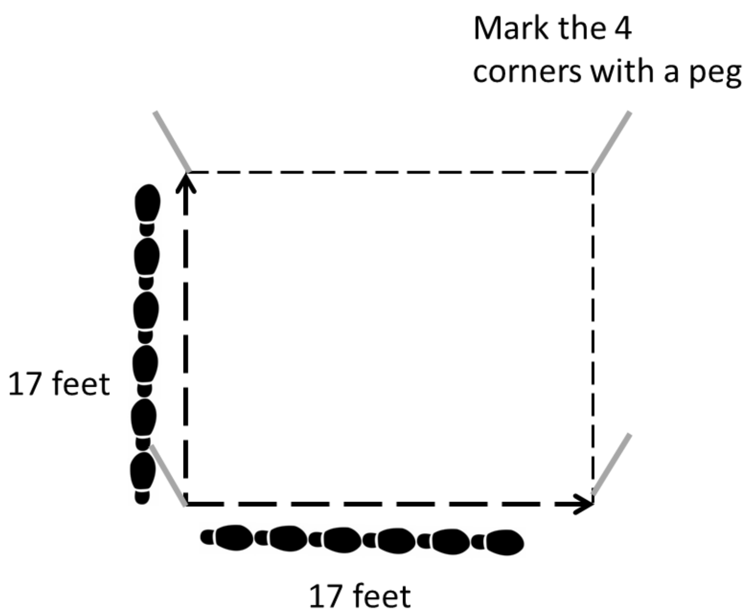
- Select land big enough to accommodate two plots of 5 by 5 meters.
- Make sure the land is even. This means that there are no trees (shade), big rocks, ant/ termite hills or other things on the plot which may influence yield.



2. Preparing the land
Prepare the land in the way that you are used to.

3. Laying out two plots

- Measure two plots of 5 by 5 meters: 5 meter is approximately 17 feet, so measure 17 feet in each direction.
- Mark the four corners of each plot with a peg so that you can easily recognize the plots.



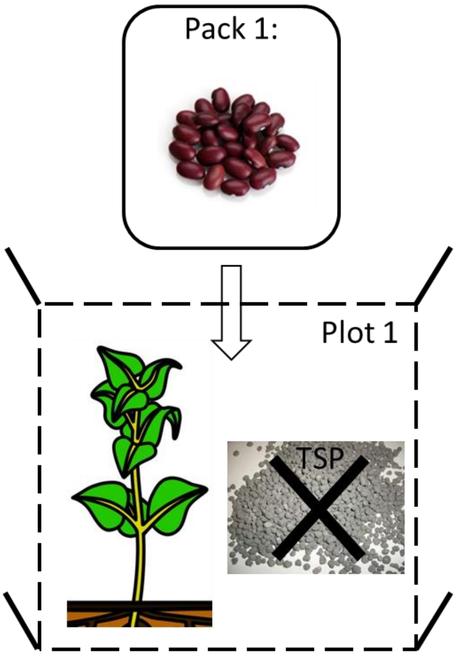
4. Manure application
If you want to apply manure, do this in equal amounts on each of the plots.

5. Sowing the plots

You have received two different packs, one for each plot. Keep the packs separate, do not mix the packs!

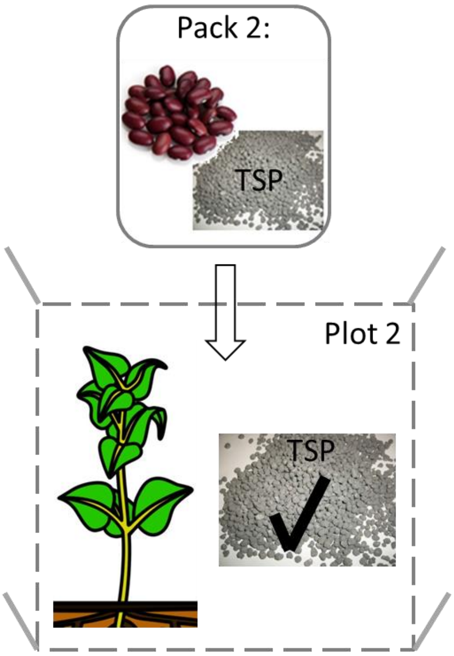
Pack 1:

- Plant the seeds from the pack on the first plot in the way that you want.
- **Do not apply fertilizer on this plot.**



Pack 2:

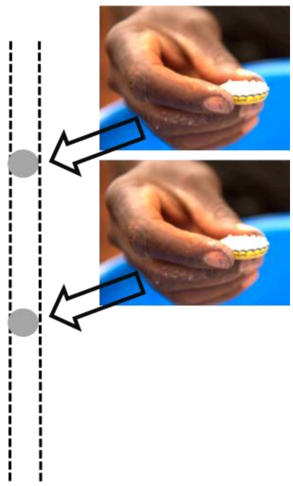
- **Apply the TSP fertilizer from the pack on this plot**. See instructions below.
- Plant the seeds from the pack on the second plot in the way that you want.



6. Fertilizer application

- Apply the fertilizer at planting.
- Place fertilizer in the planting holes/furrows and cover with 2-3 cm soil.
- Use the amounts indicated in this table:

Fertilizer type	***Rate (kg/acre)***	***In each planting hole, apply***	
		Local spacing (75x75 cm)	Spacing 25x50 cm
DAP or TSP	30	1.5 soda bottle-cap	1/3 of a soda bottle-cap



7. Staking and managing the plots

- Stake the beans in the way that you prefer or according to the treatment that you have chosen.
- Manage the beans in the way that you are used to.

8. Harvesting the plots

- Harvest the two plots separately, do not mix the yield!
- Harvest the first plot and note down the yield in e.g. kilograms, bags, bowls, or anything that is convenient for you.
- Harvest the second plot and not down the yield in the same unit.
- Keep the information until someone from the project has come to collect it.

Appendix III Fieldbook for focal adaptation trails

Field book for focal adaptation trials

Meta-data, farm typology and agronomy questions (Part 1, homestead)

A.1 Name of the person filling the form: ____

A.2 Date when form filled (DD/MM/YYYY): ________ / ________ / ________

A.3 Action site

Country: ____

State / District: ____

LGA / Sector / Ward/ Parish: ____

Village: ____

A.4 GPS coordinates of the homestead (measured at front door) **in decimal degrees**:

Latitude (North/South):______________________ Longitude (East/West): __________________________

Altitude:_________________ (meters)

Please provide information on the rainfall data corresponding to this trial

A.17 Has rainfall data been collected? Y _____ N______

Location of closest rain gauge: __________________

	collected y/n	**rain gauge identifier**	
A.17 Rainfall data collected		Closest rain gauge:	

Introduce yourself and N2Africa project. Explain purpose of survey and assure the interviewee

of the confidentiality. Make sure to check if the farmer has any questions at this time. Please note that 'you' always refers to the farmer unless indicated otherwise.

A.5 Name of the N2Africa farmer: ___________________________ Name of partner: ____________________

Sex of farmer (tick): Male ___ / Female ___ Age: _______________ years

Phone number of farmer or contact person:____

Farm ID: ____ (please assign a unique ID)

A.6 Did farmer participate in N2Africa demonstrations in previous season(s)?: Yes ___ / No ___

Did farmer fill the Field Book in previous season(s)? Yes___ / No____

If yes, in which season(s)? _________________________ Old Farm ID (look up later) ______________________

A.8 Is farmer head of the household: Yes ___ / No ___

A.9 If no, head of household is Male ___ / Female ___ and A.10 Age: ________________ years

A.11. Total number of people in the household (i.e. people currently living in the homestead).

Age	**No. of females**	**No. of males**
0 - 16 years		
17 - 35 years		
35 - 60 years		
Over 60 years		

A.12. What is the education level of the person with the highest education in the household, and the education level of the household head? **Specify the number of years** this education was attended.

(**specify number of years, write 0 for none**)?

Schooling level	**Within household**	**Household head**

1. Primary		
2. Secondary		
3. Post-secondary		
4. University		
5. A.15.11 Other, specify:________________________		

C.1 How much arable land do you have available for crop farming (incl. fallow land)?

Area: _____________ Unit: _____________

C.2 Number of valuable livestock species owned by the household

Cattle (no.):_________ Sheep (no.):_________ Goats (no.):__________

Pigs (no.):__________ Poultry (chickens, turkey, etc.) (no.): ___________

Other valuable livestock, type: _________________________ no: _________

type: _________________________ no: _________

B.1 Do you hire labour from outside the household to work in your fields? Tick what best describes your situation:

	Tick
1. Yes, permanently (i.e. every year, throughout the cropping season)	
2. Yes, regularly (e.g. at peak periods during the cropping season)	
3. Yes, sometimes (e.g. not every season or peak period, only if money allows)	
4. No, never	

B.2 What proportion of your total farm produce (cash and edible crops) is used for home consumption and what proportion for sale? Tick what best describes your situation:

	Tick
1. All produce used for home consumption	
2. Most produce used for home consumption, small part used for sale	
3. Half of produce used for home consumption, half of produce used for sale	
4. Small part used for home consumption, most produce used for sale	
5. No produce used for home consumption, all produce used for sale	

E.1 In a normal year (not a drought year for instance), which months of the year (if any) do you struggle to find sufficient food? Please tick the months with food scarcity.

	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Tick the												

months when you struggle												

In months in which you struggle to find sufficient food, are you able to buy sufficient food, or do you reduce the quantity of food/ number of meals? Tick: buy ______ / reduce quantity/ meals: ______

B.3 Importance of agriculture in the household. Please provide an estimate

of the relative importance of different sources of income by dividing the total income

into different portions. Write 0 if type of income does not apply.

	Estimated proportion of total income (in %, make sure the total equals 100%)
Cropping	
Livestock	
Casual labour in agriculture	
Casual labour off-farm	
Trade	
Other business	
Salaried job	
Pension	
Remittances	
Other________________________	

B.4 Does your household possess any of the items below? Please tick owned items.

	tick		tick

Bicycle		Tractor	
Motorbike		Plough	
Car		Ox cart/ donkey cart	
Cell phone		Tap (piped) water	
Radio		Private well	
Television		Electricity	
Fridge		Solar Power	
Sofa		Generator	
House with tiled roof and/or cement/ brick walls		Any other valuable items not listed?___________________________	
Iron sheet roof		Any other valuable items not listed?___________________________	

B.5

Estimated wealth category of household, **based on interviewer's perception, not asked to respondent** (tick)

Very poor: _____ Poor: _____ Medium: _____ Wealthy: _____

5.3.1 Questions on agronomy

C.3 How many fields did you crop **last** season: ______________________

For the fields mentioned above in C.3 (or for the 3 most important ones), please provide the following information related to the previous cropping season. If legumes are grown on another field than these 3, please fill in data on the legume field under field 4. **Please pay attention to units**.

	field 1	field 2	field 3	field 4
D.1 Size (**specify unit**)				
D.2 Walking distance of field from homestead. (in minutes)				
D.3 1st most important crop in field				
Other crops in field				
D.6 Amount of mineral fertilizer applied (0 for none, **specify unit!**)				
D.7 Type of mineral fertilizer				
D.8 Organic inputs applied Y/N				
D.9 Rhizobium inoculant applied? Y/N				
D.10 Fertility of the field (good/ moderate/poor)				

C.4 For your 3 most important crops, how much do you harvest (per area of land) in a normal year?

crop 1:_______________ amount:______ unit: _________ area of land:______ unit: _________

crop 2:_______________ amount:______ unit: _________area of land:______ unit: _________

crop 3:_______________ amount:______ unit: _________ area of land:______ unit:_________

5.3.2 Information on the N2Africa package received by the farmer and on the field where the package was planted.

D.27 Which legume package did you receive? ____

Did you plant the legume that you received? Yes___ No____

Did you use all the provided inputs for this legume? Yes___ No____

In case you did not plant the legume or did not use the inputs, what did you do?

____

____

____ What was the reason for not planting the legume or using the inputs?

____

____

D.28 We would like to know if the technologies offered in the N2Africa package were new to you, or if you already used some of these technologies before. Please tick the items in the table which were new to you.

Part of package	**Tick if this was new**
Legume species	
Legume variety	
Use of mineral fertilizer in this legume	
Inoculant	
Other ___________	
Other ___________	

5.3.3 Inoculation

I.3 Did you inoculate any legume in your N2Africa field ? Yes ___ /No ___

If yes, please answer the following questions:

I.4 Was the inoculant stored at the farm before applying? (Y/N) ___

If yes, how was it stored? ____

If yes, for how long (days/weeks/months) was it stored before use? _____ days _____ weeks ______ months

I.5 How many minutes/hours/days passed between mixing seed with inoculants and planting the seed?

_________ minutes _________ days _________ hours

A.14 If the field with the N2Africa trial **was described in part 1**, please provide the field number ______

Please record the crops that were cultivated previously in the field where the N2Africa trial is now planted. Also record the inputs that were used. Do this for the **previous season** (1 season ago) and the **season before the previous season** (2 seasons ago).

	Previous season	*Season before previous season*
D.18 Crop(s) grown in N2Africa plot (**in order of importance**)	Crop 1:	Crop 1:
	Crop 2:	Crop 2:
	Crop 3:	Crop 3:
D.19 Mineral fertilizers used (put "none" if none was used)	Type:	Type:
D.20 Organic inputs used (put "none" if none was used)	Type:	Type:
D.21 Inoculants used (put "none" if none was used)	Type:	Type:

5.3.4 Problems experienced during the growing season on the N2Africa field

D.23 Please tick whether the problems listed in the table were absent / mild / moderate / severe. Also record any other problems that occurred.

Problem	**absent**	**mild**	**moderate**	**severe**
drought				
water logging				
storm/hail				
pests				
weeds				
disease				
Other_______				

Other_______				

D.24 *If weed/pest/disease problems were reported, provide the following information (if known):*

Type of pest ______________________

Type of disease ____________________

Type of weeds _____________________

5.3.5 Observations during the growing season - Cropping calendar of N2Africa field

Please fill in the dates at which the following events occurred (if applicable)

D.22	**Activity**	**Date**	
1.	Date of land preparation		
2.	Date of organic manure application		
3.	Date of planting		
4.	Date of mineral fertiliser application		
5.	Date of 1st weeding		
6.	Date of 2nd weeding		
7.	Date of 3rd weeding		
8.	Drought period/dry spell (from-to)	From:	To:
9.	Start water logging/flooding		
10.	Storm damage		
11.	Frost		
12.	Start pest/disease		
13.	50% flowering		
14.	50% maturity		
15.	Date of (final) harvest		

Information and observations on N2Africa experiment (Part 2, field)

With this part of the survey we aim to gain in depth knowledge on the adaptation

trials. This part of the survey requires **two visits:** one field visit to **check the plots** before harvest and one visit to measure the **grain yield** after the farmer has harvested the plots. Instruct the farmer to harvest the two **entire** plots and to keep the harvest of the two plots separate. The harvest should be stored in two separate bags/ bowls/ etc. **with clear labels** until you (the technician) come back to measure the harvest. **Stress the importance of not mixing harvest from the two plots and not consuming or selling it before it has been measured!**

Some sections of this survey need to be filled in by you, **the researcher or technician**, rather than being asked to the farmer. This is always indicated with ‘*by researcher/technician*’. In other parts of the survey, ‘you’ refers to the farmer.

General - *By researcher/technician*

A.13 Kindly record the name of the researcher/ technician responsible for this part of the Field Book (contact person)

Date	Name	Organisation	Phone number

5.3.6 Description of N2Africa adaptation experiment - *By researcher/technician*
Please provide an informative experiment ID for this adaptation trial (for example: Nig_cowpea_input_001):

I.1 _Ug_CB_Kap____

Please write down the names of the two treatments provided with the package and give a brief description of each treatment. We will use the treatment names to identify the two plots throughout the field book.

I.2	Treatment **name***	**Brief description****
Treatment 1 (Control)	Nabe 12C	Climbing beans, variety Nabe 12C (250 grams)
Treatment 2	Nabe 12C + TSP	Climbing beans, variety Nabe 12C (250 grams) with TSP fertilizer (190 grams)

5.3.7 *Provide a name for the treatments in the package. For example: soybean+inoc, cowpea_local+SSP or cowpea_improved+SSP, **For example: soybean TGX 1448-2E with SSP and inoculant

Information on the N2Africa experimental field 1 - *To be measured and filled in by researcher/technician*

A.15 GPS coordinates N2Africa field (recorded in the middle of the field in decimal degrees):

Latitude (North/South):______________________ Longitude (East/West): __________________________

Altitude:_________________ (meters)

D.29 Did the farmer plant two clearly distinguishable plots with two different treatments? Yes___ No____

I.8 Please measure the width, length and number of rows of the two treatment plots

Treatment name	Width of harvested plot (m)	Length of harvested plot (m)	Number of rows in plot (if applicable)
Treatment 1* ________________			
Treatment 2* ________________			

D.11 Slope of the field (tick): 1) flat ___ 2) Moderate ___ 3) steep___

D.12 Position of field in the landscape (tick): 1) plains ___ 2) valley bottom ___

3) foot slope ___ 4) slope ___ 5) plateau ___

Please measure soil depth at three points in the field. You can measure soil depth with a thin metal stick: a soil probe. Please measure how deep you can push the soil probe into the soil until hitting a hard pan. Record the measured depths (up to 0.5m).

D.13 Soil depth (in cm, up to 0.5 m): point 1_______ point 2_______ point 3_______ cm

Information on the N2Africa experimental field 2 - *To be answered by the farmer*

D.14 Ownership of N2Africa field (tick): 1) Family land ______ 2) Hired land ______ 3) Other ______

(specify other):____

D.15 Farmer Perception of soil fertility in N2Africa field (tick):

1) Poor ____ 3) Moderate ____ 4) Fertile _____

D.16 Compared to most other fields of the farm the soil fertility in the N2Africa field is (tick):

1) Poorer ____ 2) The same ____ 3) Better ____

D.17 The drainage of the N2Africa field is (tick):

1) Good ___ 2) Moderate ___ 3) Poor___

5.3.8 Description of treatments as laid out in the fields - *To be answered by the farmer*

I.12 Please indicate for both treatments **which inputs** you used. In case you installed only one treatment (and planted one plot), fill in the tables for treatment 1 only.

	Mineral fertilizer			Inoculant	Organic fertilizer (manure, compost, crop residues)	Herbicide	Pesticide	Other input
	Applied (y/n)	*Type*	*Amount (kg/plot)*	*Used (y/n)*	*(y/n)*	*(y/n)*	*(y/n)*	*Please specify*
Treatment 1* _________________								
Reason you used this input?								
Treatment 2* _________________								

Reason you used this input?**						

*Please write down the treatment name as specified above

**When the farmer used the same input in both treatments, you don’t have to ask for the reason twice.

I.13 Please indicate **how** you planted the two treatments.

	No. of plants per stake	Stake density	Staking method	Staking material	Measure the length of 10 stakes
		Count no. of stakes in 2 rows or on 2x2 m (in case of broadc.)	Single, tripods, strings or other (describe & picture!)		
Treatment 1* ___________________	Measured and according to farmer				
Reason you did this?		Which means to get stakes, stake in time? Why delays?	Ever seen or tried other method, why (not)?	Why this m? Costs kes	Do you ever select stakes on their length?
Treatment 2*					

___________________					
Reason you did this?**					

*Please write down the treatment name as specified above

**When the farmer used the same input in both treatments, you don’t have to ask for the reason twice.

Farmer assessment of N2Africa experimental treatments

In this part we would like to get your (the farmer's) opinion on the two treatments. We would like you to give a score for each treatment. This score is represented by circles, which can be coloured to indicate the score (alternatively, the farmer could get 10 stones or coffee beans to score). 10 circles represent the best score.

What is your score for Treatment 1?:

1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0

Please explain why you give this score:

____
____
____
____

What is your score for Treatment 2?:

1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0

Please explain why you give this score:

____
____
____
____

We would also like to know how the two treatments compare to your previous experiences in case you cultivated this legume before. Please score your previous experience from 1 to 10, with 10 being the best score.

What is your score for your previous experiences with this legume?

1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0

Please explain why you give this score:

____
____
____
____

We would also like to get your opinion on the two treatments on a few specific criteria: yield, labour, costs, weeds and pests/diseases. Again, we would also like you to score your previous experience with growing this legume in case you have cultivated this legume before. Please use the following scale:

1. Very bad
2. Bad
3. Average
4. Good
5. Very good

I.14

	Treatment 1 ________________	Treatment 2 ________________	Own practice
Yield			
Labour demand			
Costs of inputs			
Weeds			
Pests/ diseases			
Other, specify:			

D.25 Are there any elements (e.g. varieties, inputs, practices) of the trial you would like to use yourself next season? If yes, please describe them:
____
____
____

Is there anything from the trial that you would like to improve? If yes, please describe what:

____

____

____

Do you have any other comments or suggestions?

____

____

____

___

5.3.9 Harvest estimation by farmer

I.15 Please record the farmers' s **own estimate** of yield **before** measuring the harvest. Ask the farmer if he/she already consumed or sold part of the harvest, and record the amount in case he/she did.

Treatment name	Yield as estimated by the farmer (in units of preference)	Please specify the unit used	Amount of crop consumed/sold (if applicable)
Treatment 1* ________________			
Treatment 2* ________________			

D.30 What is the farmer' s explanation for the observed difference or lack of difference in yield?

____

____

____

5.3.10 Harvest measurement- *By researcher/technician*

A.18Please fill in the name of the technician(s)/researchers responsible for measuring the harvest

Date	Name	Organisation

I.8 Please measure the harvest of the two plots and record the weights with a precision of 10g (two decimals on a digital scale). In case of intercropping, record the legume yield only.

Treatment name	Grain weight (Kg) in case of shelled grain	Pod weight (Kg) in case of unshelled grain
Treatment 1* ________________		
Treatment 2* ________________		

D.26. Observations during/after harvest (please provide any relevant information on the trial that you (researcher/ technician) would like to add)

____

____

____

____