Minor thesis – N2Africa

Potentials and challenges of climbing bean production in Western Kenya. Some background (theory and case studies) on technology adoption and adaptation by smallholder farmers.

How is climbing bean included as a new component of farming systems in Western Kenya and how to improve its production by smallholders?

Author: Raphaël Paut

Date: June 2013

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Abstract

Common bean *(Phaseolus vulgaris* L.*)* is the most popular legume in Western Kenya. It is the second staple food in this area, grown by 95% of farmers. However, low grain yields of the common bush bean caused by low soil fertility and sensitivity to pests and diseases are major constraints to increased food security in the region. The N2Africa project has introduced and promoted new varieties of climbing beans in order to increase beans yields. Therefore the present study analyses the potentials and challenges of climbing bean production in Western Kenya, with three main objectives: (i) to determine how climbing bean is included as a new component of farming systems in Western Kenya; (ii) to analyse the impact of staking material and method on the climbing bean production; (iii) to evaluate the adoption and adaptation of the N2Africa agricultural knowledge package by smallholders. Climbing beans were mainly used in rotation systems, on a very small area (0.057 ha). The cultivation experience for climbing beans was 1.8 years on average. Climbing beans were surprisingly not preferred by farmers owning small farms. Only 17% of farmers have replaced bush beans by climbing beans; they seemed to be included as new component of farming systems. Results showed that the adoption rate of climbing beans is increasing in Western Kenya, due to good performances. However, lack of seeds, lack of staking materials and lack of knowledge were the three main factor influencing the adoption and adaptation of climbing beans in Western Kenya. Further actions such as studies on farmer-to-farmer transmission or community based seed production are advised.

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1. Introduction

1.1. General background

This internship took place within the framework of N2Africa project. N2Africa, led by the Plant Production Systems Group of Wageningen University and implemented by the Tropical Soil Biology and Fertility Institute (TSBF) of the International Centre for Tropical Agriculture (CIAT) together with the International Institute of Tropical Agriculture (IITA), has one main goal: putting nitrogen fixation to work for smallholder farmers in Africa. Its activities span in 13 African countries (Nigeria, Ghana, Sierra Leone, Liberia, Rwanda, DR Congo, Kenya, Ethiopia, Tanzania, Uganda, Malawi, Mozambique, Zimbabwe). In Kenya, activities started in 2010, engaging international and national researchers, public universities, agri-businesses and farmer organisations. N2Africa promotes the use of different legumes; the focus legumes in Kenya are common bean (*Phaseolus vulgaris* L.), bush and climbers as well as soybean (*Glycine max* L.).

Common bean is the most popular legume in Western Kenya. Beans are grown by over 95% of farmers in the region. It is a source of cheap dietary protein and thus easily affordable for most households. However, the production of common bean is limited by several factors such as declining soil fertility, field and storage pests and diseases (especially root rot) or restricted access to fertilizers (Gichangi *et al.,* 2012). In the early 90's, Western Kenya suffered from an increasing impact of bean root rot disease resulting in substantial yield losses and decreasing food security (Mugwe *et al*., 2008). To tackle this problem, N2Africa and the International Centre for Tropical Agriculture (CIAT) worked on introducing root rot resistant varieties of climbing beans. The varieties were highly accepted by farmers who contributed to the study, although most farmers in Western Kenya consider them as new type of beans.

Climbing beans appear to be a good alternative to bush beans. The most remarkable characteristic is their high yield potential of up to 5 tons ha^{-1} compared to a maximum yield of 2.5 tons ha^{-1} for bush beans (CIAT, 2004). They can have other diverse utilizations, e.g. as soil cover, and due to their high nitrogen fixing capacity they can play an important role in crop rotation and the management of soil fertility (Mucheni *et al*., 2007). Climbing beans are able to climb up to 4 meters but they need good supporting materials and relatively high labour input for staking. When climbing bean is intercropped, the other crop (mainly maize and banana) serves as stake, but with reduced yield of both climbing bean and the companion crop(s). In monoculture, the staking materials are wood stakes, wires or strings. By allowing a vertical growth and improving aeration, which reduces the influence of pests and diseases, the support greatly influences in the final yield. Moreover, climbing beans can produce up to 17-25 tons of leaves per hectare (KARI, 2008); this wealthy biomass can be consumed by animals or provide organic matter to the soil when not harvested.

According to the literature, the major limiting factors for the expansion of climbing bean production are (i) the lack of improved seeds and the scarcity of staking materials; (ii) the longer growth period (4 months instead of 3 months for bush beans); and (iii) increased labour requirements (CIAT, 2004; Ojiem *et al.,* 2006; Ramaekers *et al.*, 2013). Therefore, this study analysed the potentials and challenges of climbing bean production in Western Kenya.

For this purpose, questionnaires, interviews and field observations were conducted with a representative sample of farmers in the study area.

1.2. Objectives

The overall objective was to evaluate the potentials and challenges of climbing bean production in Western Kenya in order to provide recommendations for improvement. Specific objectives were to:

i. Determine how climbing bean is included as a new component of farming systems in Western Kenya.

ii. Analyse the impact of staking material and method on the climbing bean production.

iii. Evaluate the adoption and adaptation of climbing bean technology package by smallholders.

The above objectives are built around the following research questions

i. Do farmers have any preference on climbing beans than bush beans (Why do farmers grow climbing beans? What cropping system is used? On which fields are climbing beans preferably cultivated (location within the farm and soil fertility gradients)? What are farmers' perceived advantages of climbing bean cultivation over bush beans? What are the challenges associated with growing climbing beans?)

ii. Do farmers perceive staking materials a constraint to grow climbing beans and if so what are they doing to solve the problem (What staking methods and material are used? To what extent does this influence the yield? What are farmers doing to solve the problem of staking?)

iii. Has N2Africa made any impact to the farmers with regard to growing climbing bean? (What did farmers learn about growing climbing beans from the N2Africa project? Seeking to understand the reasons for adoption -or not- of climbing beans?)

iv. I which ways farmers have adapted growing of climbing beans (What adjustments have farmers made compared to what has been demonstrated by the N2Africa project? What do farmers do differently and independently?)

2. Materials and method

2.1. The study area

The study was conducted in Western Kenya (Fig. 2.1), in counties Vihiga (MFAGRO and AVENE farmers groups), Bungoma (BUSSFFO farmers group) and Kakamega (Kleen H&G farmers group). Detailed characteristics of the counties are summarised in Table 2.1.

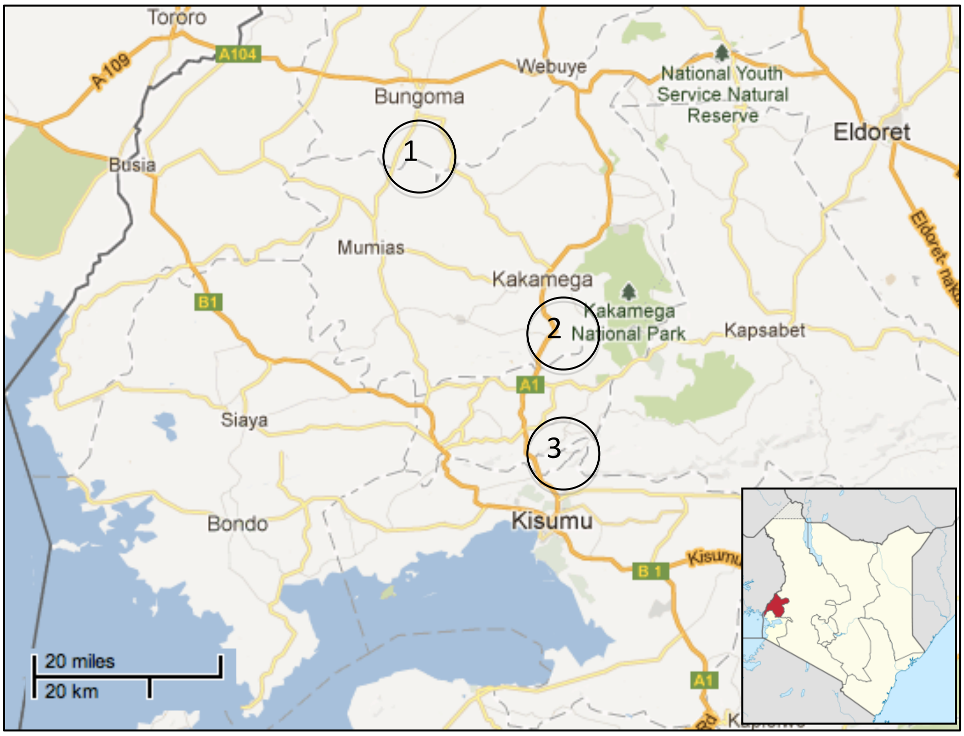


Figure 2.1: Map of Western Kenya showing the location of farmers groups in Bungoma County (1), Kakamega County (2) and Vihiga County (3). Source: Google Map, 2013.

Table 2.1: Site characteristics of N2Africa action sites in Western Kenya.

Site	Vihiga	Bungoma	Kakamega
Agroecological zone	Upper Midlands	Midlands / Upper Midlands	Midlands / Upper Midlands
Population density (Inhabitants km-2)	1200	460	440
Annual rainfall (mm)	1800±200	1590±182	1672±68
Annual mean temperature (°C)	21	20	20
Length growing period (d)	315	278	325
Farm sizes (ha)	0.6	1.8	1.2
Household sizes (#)	6-8	6-10	6-8
Main staple food	Maize, beans	Maize, beans	Maize, beans

Source: Franke *et al.*, 2011b.

Western-Kenya is densely populated, resulting is small landholdings. The region has high agro-ecological potential and a high market access. Rainfall is relatively high and the growing period is relatively long (from 278 to 315 days) making the region suitable for agriculture and livestock keeping. Maize is grown on the vast majority of lands usually as main crop, while common bean is the second most important crop. Other important crops grown on more than 10% of all fields are groundnut, sugarcane, cassava, bananas and cowpea (Franke *et al.,* 2011a).

Soil fertility is declining in many areas because of extensive soil degradation (Tittonell *et al.*, 2005). Soils in Western Province have mainly developed on basement rocks, which are normally not rich in nutrients. For years, heavy rains have leached the soils considerably. Today a dense population needs to cultivate continuously; thus the nutrient content of the soils is diminishing at an alarming rate raising concerns on the sustainability of food production (Table 2.2). Therefore there is a need to revitalise the degrading soil fertility through improved management practices and suitable crop rotations including legumes.

Table 2.2: Decrease (%) of pH and potassium in typical soils of Western Province as an example of the rapid loss of nutrients (during 5 years of maize cultivation at the "Fertiliser Use Recommendation Project" (1986-91) experimental sites).

FURP Site	Soil	AEZ	Decrease of pH		Decrease of K	
			Contr.[1]	Fert.[2]	Contr.[1]	Fert.[2]
Kakamega Western Agric. Res. Station (Kakamega District)	Dystric-mollic Nitisol	UM 1	-2.6 %	-10.2 %	-4.3 %	-20.5 %
Mwihila (Kakamega District)	Dystric Nitisol	LM 1	-2.7 %	-4.2 %	-16.7 %	-38.1 %
Vihiga-Maragoli (Vihiga District)	Chromic to orthic Acrisols	UM 1	-7.8 %	-7.8 %	-15.0 %	-23.8 %
Bukiri-Buburi (Busia District)	Rhodic to orthic Ferralsols	LM 3	-6.0 %	-9.5 %	-25.0 %	-33.3 %

[1] Control: without fertilizer and/or manure

[2] Fertilization: 75 kg N and 75 kg P per ha and year

Source: Jaetzold *et al.*, 2005.

2.2. Data collection and study population

To collect information on the use of climbing beans as a new component of farming systems and on the use of stakes, a survey was conducted with farmers growing bush beans and climbing beans. The study population consisted of households involved in the N2Africa project in Vihiga County (Kleen H&G and AVENE groups), Bungoma County (BUSSFFO group) and Kakamega County (MFAGRO group). Sampling was done for each county based on bean production (climbing beans or bush beans) as primary sampling unit, household head gender as secondary sampling unit and household wealth class as tertiary sampling unit (Fig. 2.2). Wealth classes were poor, medium and rich resource endowed, according to master farmer's observations (land size, cattle, and asset). The questionnaires (Appendix 1 and 2) asked for quantitative and qualitative information and were structured in five sections; (i) household information, (ii) crop production, (iii) bush beans production (if any), (iv) climbing beans production (if any) and (v) staking material (if any). Questionnaires were pre-tested with a few farmers and adjusted where needed. The survey was carried out in April-May 2013 with the help of four N2Africa enumerators who spoke the local dialects. In order to have a uniform dataset and a common understanding of the research aims, the enumerators were trained by the researcher before the beginning of the interviews.

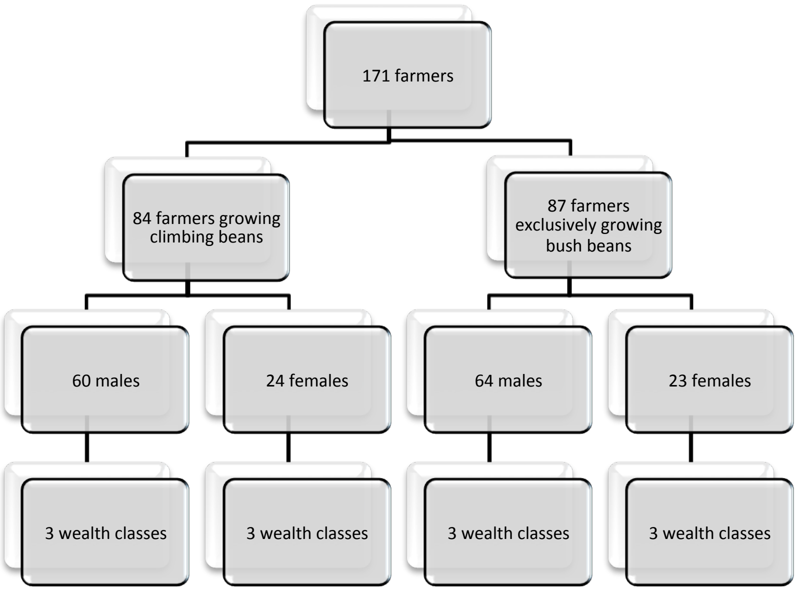


Figure 2.2: Sampling method and number of farmers interviewed at each level.

Regarding the adaptation of climbing bean technology package by smallholders, additional interviews and field visits were conducted with a group of 20 farmers growing climbing bean, selected from the same sample of farmers, according to the staking method they used. The aim was to collect information about farmers' initiatives and adaptation of technology packages for climbing bean production in relation to what was demonstrated by the N2Africa project. During this process the information was gathered about stake density, plant population density, distance of the climbing bean field from the homestead and the cropping systems of climbing beans. The detailed field measurement form is appended ad Appendix 3.

2.3. Data management

The survey data were analysed with SPSS software version 20. The database was first cleaned in order to remove data entry errors and incoherent information. A descriptive statistical analysis was done in order to summarize climbing bean and bush bean production characteristics. A one-way ANOVA was applied to compare the difference between climbing bean and bush bean production attributes. Differences in treatments means were tested at a probability (*P*) at <0.05. The extra group of 20 climbing bean growers selected for measurements and interviews was only used for descriptive analyses.

3. Results

3.1. Climbing beans production

The average farm size of farmers growing climbing beans and bush beans was 0.97 and 0.86 ha respectively and did not differ between the two groups (Table 3.1). However the area allocated to each crop differed (*P*<0.01), where climbing beans accounted for 11% of the farm area and bush beans were cultivated on 43% of total lands area.

Table 3.1: Characteristics of climbing beans and bush beans fields

Parameter	Climbing beans	Bush beans
Farm size (ha)	0.97 a[1]	0.86 a
Area cultivated with beans (ha)	0.06 a	0.43 b
Manure and organic fertiliser (% of farmers)	77 a	80 a
Fertiliser: DAP, NPK, CAN, Sympal (% of farmers)	55 a	56 a
Production used for sales (%)	25 a	28 a
Cultivation experience (years)	1.79 a	17.21 b

[1] Different letters in the column indicate differences between means (P<0.05) for each variables, according to the F-test (one-way ANOVA).

Both groups of farmers equally used organic manure to grow beans. They used mainly animal manure and few of them (13 farmers in total) used compost as organic fertiliser. Regarding the use of mineral fertilisers, there was again no significant difference between both farmers groups. Fertilisers used were di-ammonium phosphate (DAP - 50%), nitrogen phosphorus potassium (NPK - 5%), calcium ammonium nitrate (CAN - 3%) and phosphorus potassium calcium sulphur magnesium (Sympal - 42%). Bush bean growers used mainly DAP whereas climbing bean farmers used preferably Sympal (Fig. 3.1). 58% of climbing beans farmers used the Biofix inoculant. Finally, the amount of the production used for sale was 25% and 28% for climbing beans and bush beans respectively. Beans were sold on the local market. Generally speaking, bush beans and climbing beans received the same treatment except for the plot size, the type of fertiliser and the use of inoculants.

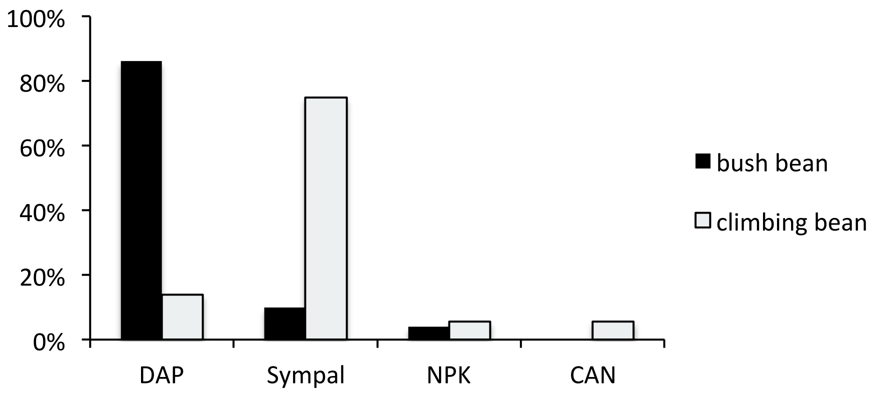


Figure 3.1: Type of fertiliser used by farmers

A slight difference was found regarding the source of household income. 99% of bush beans growers claimed that crop production was the main source of income, while only one farmer mentioned livestock as the main source of household income. On the other hand, among climbing beans growers, 90% of farmers reported that crop production was the main source of income, while the 10% remaining referred to off-farm income.

Concerning the cropping systems, climbing beans were mainly cultivated in rotation with cereals (92%) whereas the remaining six farmers intercropped climbing beans with maize. When rotated, climbing beans were mainly followed by maize (57.6%) then by vegetables (34.8%) and finally by other crops (soybean, millet; 7.6%).

Focusing on the location of both types of beans within the farm (Fig. 3.2), climbing beans were mostly grown in in-fields (close to the household), usually on fertile soils since they need more attention and more labour. On the other hand, 70% of farmers grew bush bean on mid and out-fields. See appendix 4 for more details about the location of fields within the farm.

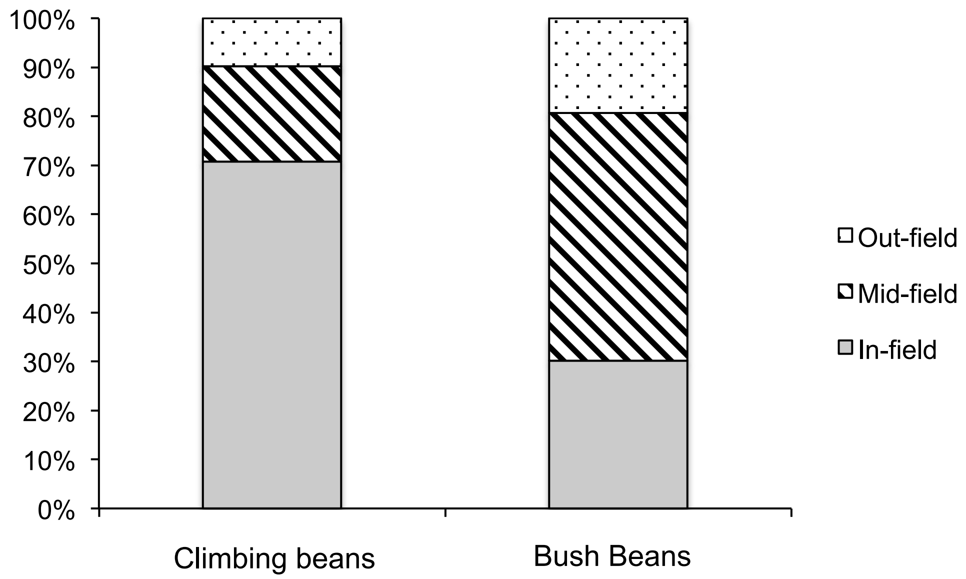


Figure 3.2 Fields location within the farm

Climbing beans are a relatively new crop in Western Kenya. The climbing beans varieties grown were Kenya Tamu and RWV 13148. On average, farmers grew them for the first or second season (1.8 years on average). On the other hand, several bush bean varieties have been cultivated for more than 17 years by most of the farmers. Being a new crop, climbing beans have replaced other crops. Unexpectedly, only 17% of farmers have replaced bush beans by climbing beans (Fig. 3.3) Climbing beans succeeded vegetables (Sukuma wiki, sweet potato – 38%); other legumes (lablab, soybean, cowpea, bambara groundnut – 27%); maize and Napier grass (12%) and sugarcane (5%).

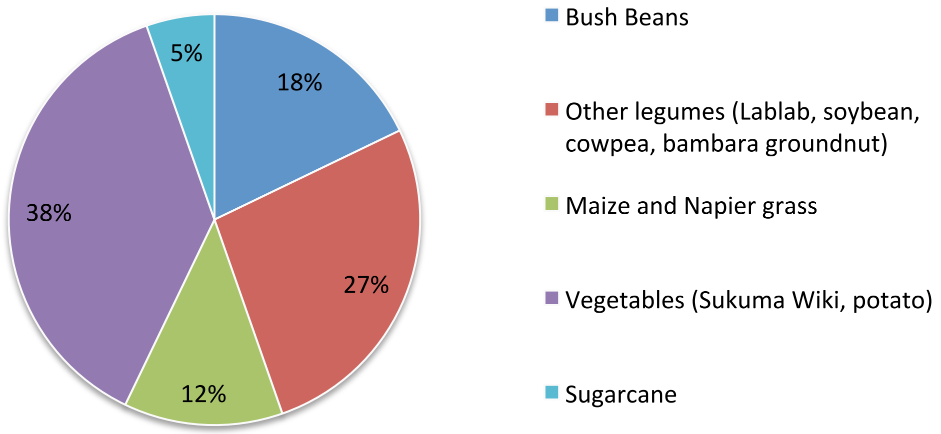


Figure 3.3: Crop replaced by climbing beans

3.2. Methods and materials used to support climbing beans

Farmers in the survey used five different methods to support climbing beans including staking methods (individual stakes, tripods, intercropping with maize), strings and living trees (Figure 3.4). Some farmers used several methods at the same time.

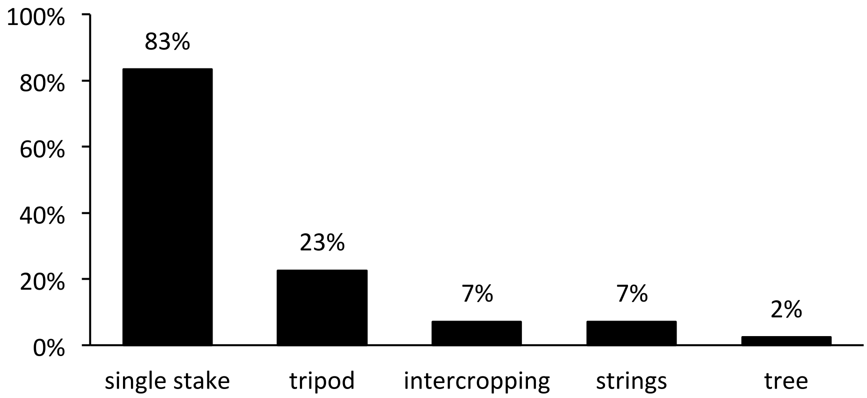


Figure 3.4: Percentage of farmers using different staking methods.

3.2.1. Staking method

Individual stakes

The vast majority of farmers used single stakes (Figure 3.5), where one stake supported up to 4 plants if the stake was strong and the soil is deep. However, in most cases one stake supported one single plant. The most important species used as stakes were *Eucalyptus*, *Calliandra*, *Cupressus*, *Grevillea* and some indigenous species such as *Markhamia lutea* and *Lantana sp*.

Figure 3.5: Single staking method

Tripods

Tripod (Figure 3.6) is the second most important method used by farmers to support climbing beans. They are formed from three stakes tied together. The main advantage of using tripods is their strength. Especially on shallow soils the tripod was preferred. They also have the advantage to be a windbreaker. Each stake supports one to three plants as shown in the drawing below.

Figure 3.6: Tripod staking method

Intercropping with maize

When staking materials were scarce or too expensive, climbing beans were grown in intercropping with maize. There were two ways of intercropping (Figure 3.7);

i. Sowing climbing beans two weeks after maize in order to have maize stems strong enough to support climbing beans.
ii. Sowing climbing beans right after the maize harvest so that the remaining maize stem serves as stake. This method is called relay cropping.

Farmers mentioned that maize stems were eaten by the maize stalk borer *(Busseola fusca)* when they used the second method. Both crops are either arranged in alternate rows (*row cropping*) or mixed within rows (*mixed cropping*).

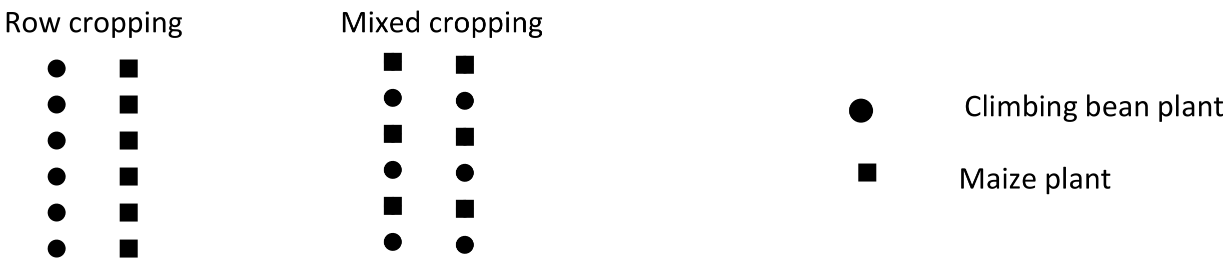


Figure 3.7: Intercropping methods

3.2.2. Other method used to support climbing bean

Strings

Another method practiced by few farmers (7%) was the use of strings. Ropes are tightened horizontally between two strong stakes (Figure 3.8). From this rope, numerous other ropes fall vertically over the climbing beans to serve as stake. This method however requires strong poles and ropes with good strength in order to support the accumulated weight.

Figure 3.8: String support method

Trees

Very few households (2) used trees to support climbing beans. One farmer used Calliandra fodder trees in order to support climbing beans. The other planted climbing beans under coffee trees. In each case it was about few seeds for trial.

3.2.3. Source of stakes and stakes life-span

Among the interviewed farmers using stakes, only one third purchased them. The remaining farmers obtained them from trees grown on their own fields, and few of them fetched stakes from the surrounding farm area. Poor resource endowed farmers grew and fetched stakes whereas majority of medium and rich resource endowed farmers grew and purchased them. A difference was found between sites; a vast majority (93%) of farmers in Bungoma County grew stakes on field. In Kakamega County 48% of farmers grew stakes and 32% purchased them. In Vihiga County, 44% of farmers grew stakes and 50% purchased them (Fig. 3.9). The price per stake was highest in Bungoma county (20 KShs on average), which could explain why most of the farmers in this county grew them on their own field. The average price per stake in all the counties ranged between 3-50 KShs (1 KShs equals 0.01192 USD) with an average of 13.75 KShs. Farmers replaced their stakes every 1-2 years (2-4 seasons) and sometimes every 3 years. According to the average area planted with climbing beans, the average staking density and the average price of stakes, the expense regarding stakes is 23,925 KShs per farmer buying stakes.

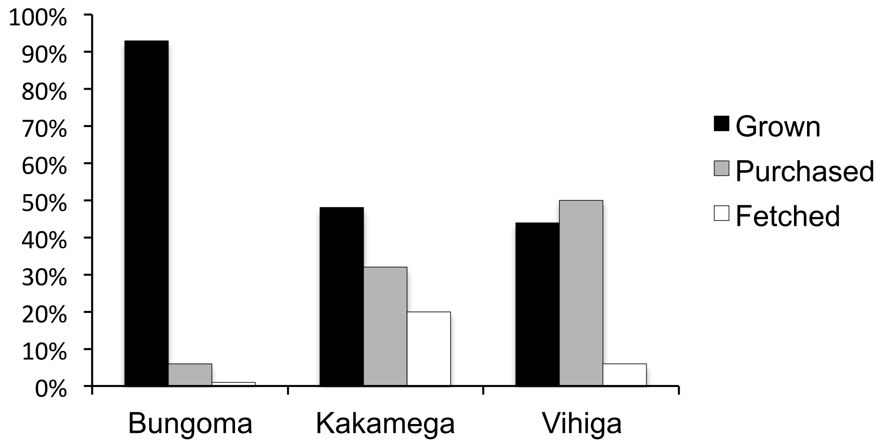


Figure 3.9: Percentage of farmers growing, purchasing or fetching support materials (stakes) in three counties of Western Kenya.

When farmers were asked the question "is staking a constraint for you?" 92% of climbing bean farmers answered yes. Among these farmers, it was mentioned that stakes (i) are costly; (ii) are hard to find; (ii) do not last long; (iv) can be eaten by termites; (v) can be broken by wind or high yields. Nevertheless, some farmers did not perceive staking as a problem and developed some initiatives to cope with their shortage. They grew their own trees when they had land available, shared stakes, from one season to another, with friends and neighbours in order to make the most of one stick, and they used intercropping when stakes were not available. It was also mentioned that stakes are useful as firewood after their use.

3.3. Climbing beans adoption and adaptations

3.3.1. Adoption of climbing beans

According to master farmers, the adoption rate of climbing beans is increasing in Western Kenya, due to good performances. The early adopters showed satisfactory results and therefore caught friends and neighbours' attention on relative advantages of climbing beans over bush beans. One can see farmers testing climbing beans on farm borders with few seeds given by a friend.

There are different reasons why farmers adopted climbing beans; the main one being its high productivity (Fig. 3.10). The other reasons were, in order of importance:

- A sweeter taste, compared to common beans. That makes it attractive and therefore there is a high demand and a higher price on the market.
- High capacity to fix nitrogen and for soil fertility improvement.
- Land scarcity; climbing beans do not need a lot of space to be cultivated.
- Easy to harvest due to a vertical growth.

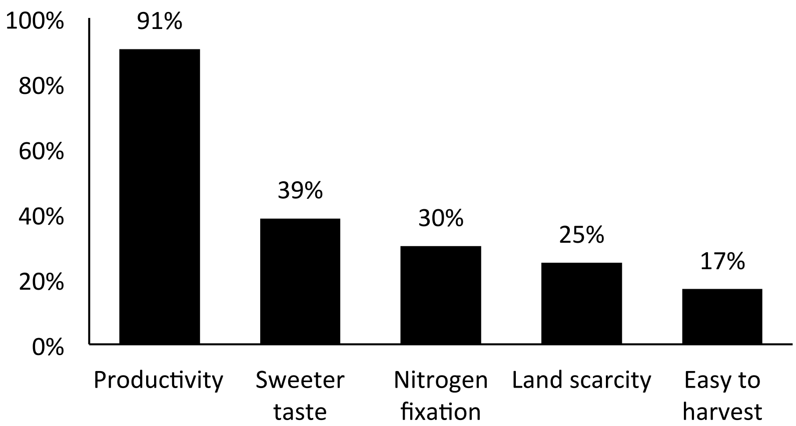


Figure 3.10: Reasons given by farmers for the adoption of climbing beans

The survey allowed highlighting some constraints for climbing beans production and therefore adoption. When farmers were asked about challenges of growing climbing beans, six typical answers were identified, namely: (i) shortage of staking material; (ii) high incidence of pests and diseases; (iii) labour intensiveness; (iv) birds; (v) lack of seeds and (vi) lack of knowledge. Those answers are presented in Figure 3.11. The outer limits of the chart represent 100% of positive answers whereas the centre of the chart means 0% of positive answer. The questions were asked to both climbing beans and bush beans growers. Bush beans farmers were asked both questions on "reasons for not growing climbing beans" and "disadvantages of climbing beans", but these two questions were overlapping, farmers gave the same answer for both questions.

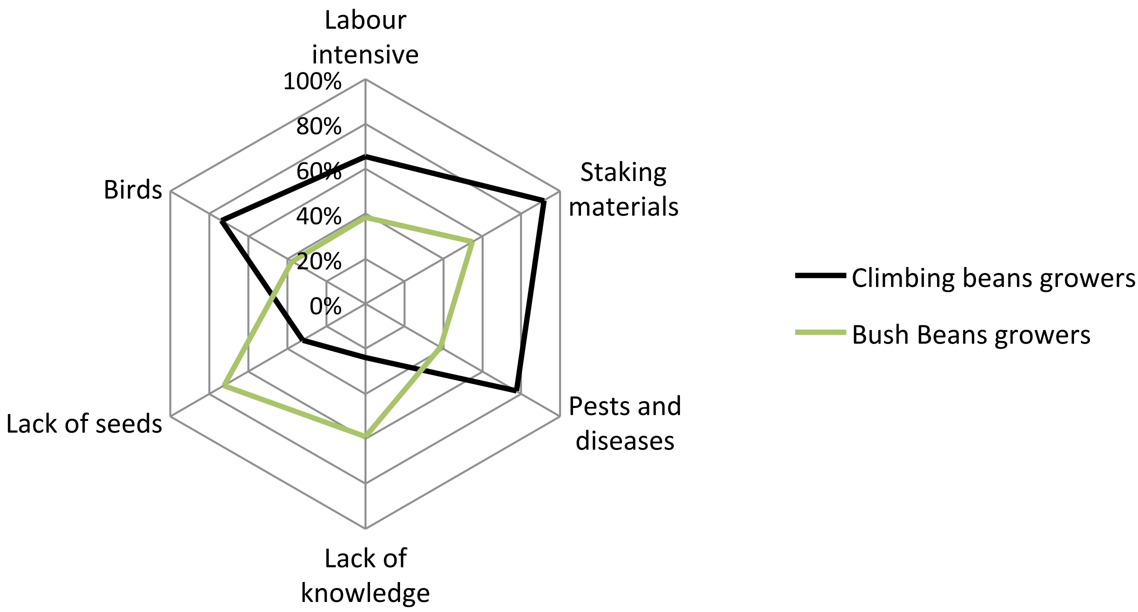


Figure 3.11: Climbing beans production constraints as perceived by farmers

Clearly, climbing bean growers oriented their answers toward production constraints (birds, labour, staking materials, pests and diseases) whereas non-growers oriented their answers toward the poor availability of climbing beans (lack of knowledge and lack of seeds).

On the other side, farmers who were not growing climbing beans, 63% was aware of them. Nearly all farmers became aware through the N2Africa network; the remaining part became aware through friends and neighbours. Among those farmers who did not grow climbing beans, two groups can be distinguished. The first group consists of farmers who grew climbing beans before but who stopped (21% of bush beans growers). This group gave three main reasons for not growing climbing beans anymore: (i) growing climbing beans is labour intensive; (ii) lack of staking materials; (iii) there is a lack of seeds. The second group consists of farmers who have never grown climbing beans (79%). They justified their decision by: (i) the lack of seeds (73%); (ii) the lack of knowledge (59%); (iii) the scarcity of staking materials (55%).

Another constraint for the adoption of climbing beans was not visible through the survey but came out during the field outings. This was associated to the gender of the farm labour. Indeed, it was mentioned repeatedly that climbing beans, considering that it is a labour intensive crop, is less likely to be adopted by women. But at the same time, more and more men are leaving households to get off-farm income.

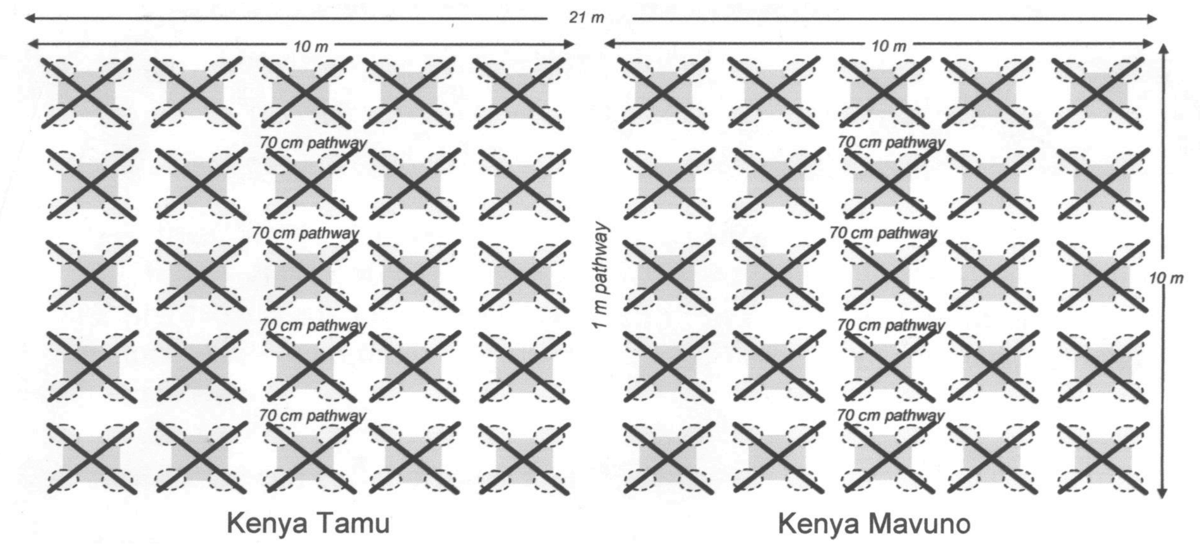
3.3.2. Adaptation of climbing beans technologies

When the N2Africa project started, farmers were not used to staking any crops, therefore staking of climbing beans has been an important issue for the project to focus on. There was a clear difference between what was advised by the N2Africa field protocol, what was demonstrated to farmers and what farmers were doing independently. Thus the following part is divided into 3 sections. The staking methods are described in the section 3.2.1.

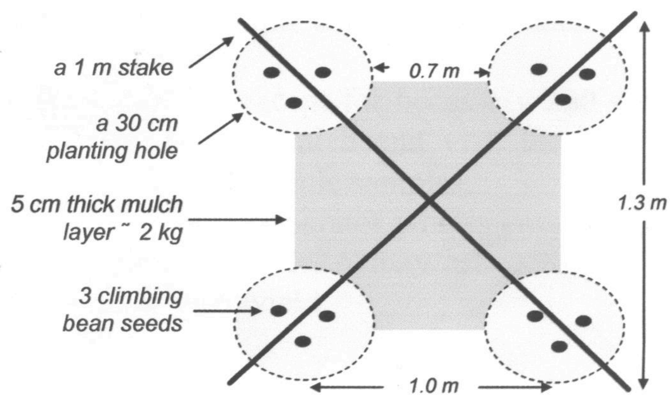
- **N2Africa field demonstration protocol**

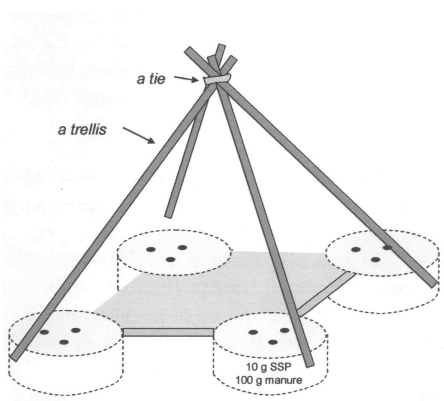
From inception, the N2Africa Kenya Outreach Team had one main goal: secure a quantity of two new climbing bean varieties, Kenya Mavuno and Kenya Tamu. It started in 2010; the highest priority was to multiply these seeds for network use during the next growing seasons. N2Africa provided all necessary inputs; namely 2 kg P fertilizer, 200 g seed of each improved variety of climbing beans, 100 ml of 16% gum Arabic sticker solution, and a 50 g packet of BIOFIX legume inoculant. Stakes and manure were not provided.

The demonstration field had to be arranged as follows:



The demonstration plot should cover an area of 210 m^2, separated into two 10 m × 10 m plots by a 1 meter wide pathway. The demonstration should have contained two climbing bean varieties supported by 50 trellises. Trellises should be arranged as follows:





- **N2Africa collaborator demonstration fields**

On the demonstration fields, different staking methods were being demonstrated to farmers, depending on the master farmers' initiative. Within Kleen H&G group, single staking, tripods and strings were demonstrated. Within MFAGRO group, single staking, tripods and intercropping were demonstrated whereas in BUSSFFO and AVENE groups, only single staking was demonstrated (Table 3.2).

Table 3.2: Staking method demonstrated by groups

Group	Staking method demonstrated
Kleen H&G	Single staking, tripod, strings
MFAGRO	Single staking, tripod, intercropping
BUSSFFO	Single staking
AVENE	Single staking

Measurements were taken on demonstration fields, during maize and climbing bean growth, in order to calculate the plot size, the length of stakes, the staking density (number per m^2), the number of plants per stake and finally the plant density (number per m^2). When tripods were used, the distance between stakes within a tripod was calculated. The length of stakes (in cm) was measured for at least three average, three tallest and three of the shortest stakes in a specific field. A summary of the demo-plots characteristics can be found in Table 3.3. The relative contribution of the highest, average and lowest stakes was heterogeneous; average stakes were more numerous than the others, while highest stakes were scarcer than the others.

Table 3.3: Demo-plot characteristics per staking method and per group.

Staking method	Group	Staking material	Plot size (m2)	Highest (cm)	Average (cm)	Lowest (cm)	Stake density (number.m^{-2})	Number of plant per stake	Plant density per m^2	Distance within tripod (cm)
Single	MFAGRO	mixed[1]	58.3	260	200	170	2.20	2	4.4	-
Single	AVENE	mixed	33.5	320	200	170	4.03	1	4.0	-
Single	BUSSFFO	Cypres	69.8	ns[1]	ns	ns	2.71	1	2.7	-
Single	BUSSFFO	mixed	33.3	310	210	145	2.70	1	2.7	-
Single	Kleen H&G	mixed	221.9	ns	ns	ns	3.32	1	3.3	-
		Average:	**83.36**	**296**	**203**	**162**	**3.0**	**1.2**	**3.4**	**-**
Tripod	MFAGRO	mixed	154	320	250	190	1.29	4	5.1	60-100
Tripod	Kleen H&G	Calliandra	212.8	ns	ns	ns	1.05	3	3.2	90-100
		Average:	**183.4**	**320**	**250**	**190**	**1.17**	**3.5**	**4.15**	**87.5**
Inter-cropping	MFAGRO	maize	**64.66**	**mh[3]**	**mh**	**mh**	**2.78**	**1**	**2.8**	**-**
Strings	Kleen H&G		**208.24**	**ns**	**ns**	**ns**	**2.61**	**1**	**2.6**	**-**

[1]mixed: stakes are made from mixed local species.
[2]ns: climbing beans were not staked at the moment of the measurement.
[3]mh: the stake length depends on the maize height.

- **N2Africa farmers' fields**

Next to the N2Africa demonstration fields, farmers were also growing climbing beans independently. They adapted the technology according to their situation. This section focuses on the differences between what was demonstrated to farmers compared to what farmers were actually doing. Table 3.4 describes the farmers plot characteristics.

Table 3.4: Farmers plots characteristics.

Farmer code	Staking method	Staking material	Plot size (m^2)	Highest	Average	Lowest	Stake density (number m^{-2})	Number of plant per stake	Plant density per m^2	Distance within tripod (cm)
1	Single	mixed[1]	70.2	420	180	90	2.82	1	2.8	-
2	Single	mixed	11.4	220	170	100	3.93	1	3.9	-
3	Single	mixed	27.7	300	220	155	4.76	2	9.5	-
4	Single	mixed	33.5	320	200	170	4.03	2	8.1	-
5	Single	mixed	39.2	240	130	80	2.86	1	2.9	-
6	Single	mixed	fs	-	-	-	nm	1	nm	-
7	Single	Bamboo	60.8	240	190	145	1.74	1	1.7	-
8	Single	mixed	9.52	450	210	140	4.41	1	4.4	-
9	Single	Calliandra	57.7	250	195	140	2.67	1	2.7	-
10	Single	Calliandra	36.5	260	180	120	3.31	1	3.3	-
11	Single	Calliandra	82.6	250	180	110	0.98	1	1.0	-
12	Single	mixed	97.8	330	230	160	0.59	2	1.2	-
		Average:	**47.9**	**298.2**	**189.5**	**128.2**	**2.9**	**1.3**	**3.8**	**-**
13	Tripod	mixed	75.1	260	180	140	0.80	2	1.6	60 to 100
14	Tripod	mixed	fs[2]	350	160	140	nm	1	nm	40 to 60
		Average:	**75.1**	**305**	**170**	**140**	**0.80**	**1.5**	**1.6**	**65**
15	Intercrop	mixed	nm	230	160	140	nm	1	nm	-
16	Strings	Manilla	56.1	205	205	205	3.48	1	3.5	-

[1]mixed: stakes are made from mixed local species.
[2]fs: few seeds. The farmer planted few seeds then the plot size is not measurable.
[3]nm: non-measureable.

From Table 3.3 and 3.4, an additional table is made in order to compare characteristics of demo plots and farmers' plots. The plot size was clearly lower than demonstrated for farmers, except for intercropping. The small land size could be explained by both land scarcity and poor seed availability to farmers. Regarding the stake height, the longer stakes were in a similar range for farmers and demo-plots, while the average and lowest stakes were clearly lower for farmers. Since the average and lowest stakes are the most widely used, this makes a significant difference. The staking density was identical for single staking but much lower for farmers using tripods and intercropping. The farmers using strings increased string density compared to the demo. The number of plants per stake was generally the same, except for tripods where farmers used fewer seeds per stake than demonstrated. Finally the climbing bean density was acceptable for single stake and string method, but really under expectations for tripod and intercropping.

Table 3.5: Comparison between demo plots and farmers' plots

	Plot size (m^2)	Highest	Average	Lowest	Stake density (number m^{-2})	Number of plant per stake	Plant density per m^2	Distance within tripod (cm)
Single stake demo	83.4	296	203	162	3.0	1.2	3.4	-
Single stake farmer	47.9	298.2	189.5	128	2.9	1.3	3.8	-
Tripod demo	183.4	320	250	190	1.17	3.5	4.15	87.5
Tripod farmers	75.1	305	170	140	0.80	1.5	1.6	65
Intercrop demo	64.6	mh[1]	mh	mh	2.78	1	2.8	-
Intercrop[2] farmer	75.1	305	170	140	0.80	1.5	1.6	-
Strings demo	208.2	ns[3]	ns	ns	2.61	1	2.6	-
Strings farmer	56.1	205	205	205	3.48	1	3.5	-

[1]mh: the stake length depends on the maize height.
[2i]nercrop famer: the farmer used intercropping with maize but staked climbing beans
[3]ns: climbing beans were not staked at the moment of the measurement.

Among demonstration fields, the most used staking method was (i) single staking; (ii) tripod; (iii) intercropping and (iv) strings. This was also observed in farmers' fields (Fig. 3.3). In this way, farmers were true to what they were demonstrated. However, they did some adaptations and modifications on the climbing beans production: plot size, stake height, staking density and therefore climbing bean density. Some farmers even used methods that were not demonstrated, namely tree staking or intercropping single staked climbing beans with maize (in this case, farmers actually intercropped maize and climbing beans, but still used wooden stakes). According to farmers, scarcity of staking material and seeds are the two factors that made them adapt the technology on their fields.

4. Discussion and conclusion

Although climbing bean is a relatively new crop in Western Kenya, the present research allowed highlighting some constraints and opportunities for climbing bean production in this region.

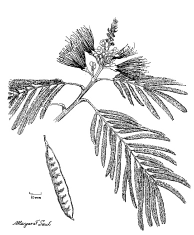
Lack of knowledge affects mainly farmers who did not know how to grow climbing beans. Although 63% of non-growers claimed to be aware of climbing beans, mainly through N2Africa, the lack of knowledge remains a major constraint to their adoption. The crop is still perceived as a newly introduced technology. In some areas, demo plots existed but they were few. The emphasis was clearly on soybeans and farmers had poor access to the climbing beans technology. The most striking example to illustrate this issue is the use of Biofix inoculant. 58% of climbing beans farmers used Biofix inoculant on climbing beans whereas researches in the project reported inconsistency results from use of Biofix had no clear effect on yields of climbing bean. This shows that there is incoherence in the knowledge diffusion. In order to increase farmers' awareness on climbing beans, N2Africa needs to continue and increase demonstrating, especially on roadsides in order to reach more farmers. The use of Information and Communications Technology (ICT) is also advisable, mainly phones and radios in Western Kenya. Stienen *et al.* (2007) reported that ICT could actually make a great difference in agricultural livelihoods. In the same way, Agwu *et al.* (2008) showed that radio farmer programmes enhanced the extent of adoption of agricultural technologies. Further extension activities could take this means into account in order to reach more farmers.

Labour shortage. The labour required to grow climbing beans is a major constraint for producers. That can explain why farmers did not replace common beans with climbing beans. The labour that climbing beans require makes it impossible to cultivate on big fields. It is also the main reason that makes farmers stop growing climbing beans (94%). One can assume that with an increasing adoption of the crop and an increasing cultivation experience, farmers would be used to climbing beans, therefore become more efficient and the production would be less time-consuming. Further studies to quantify labour productivity from growing climbing beans would be useful.

Birds. There is no known effective method for controlling birds, whereas birds affect both flowers and tender bean pods. Farmers are currently using magnetic tape stripes to frighten birds off but this method turns out to be inefficient. However, in the long term, once farmers get convinced of the benefits of climbing beans, more will adopt it, one can assume that farmers would thereby share the bird burden and minimize yield losses associated with the pest.

Staking materials. This is the most important production constraint according to farmers. Even though some farmers came up with few solutions to cope with stakes (see section 3.2.2), 92% of farmers consider staking as a constraint. In some areas, proper staking materials are extremely scarce or expensive. That makes the production not affordable or not profitable for many farmers. N2Africa promotes (among other fast growing legume trees) the use of *Calliandra* legume-tree (see description on Text-box 1). However, majority of farmers used local trees growing on the field edges. 68% of farmers used short stakes (less than 140 cm) while the length of staking is probably the most important factor for a high production of climbing beans. Therefore future promotional activities should again emphasize on the importance of using sufficiently long stakes.

Calliandra calothyrsus



Calliandra is a small, thornless leguminous tree with characteristic pink flowers. It is native to Central America and Mexico. It is rarely utilised in its native range but it has been introduced to many tropical regions, such as western Kenya, where it is used in agroforestry systems for firewood, plantations shade, as an intercrop hedgerow and more recently as livestock forage.
Its early growth is slow, but once mycorrhizal infections have become effective it grows vigorously up to a height of 3.5 m in 6 months. Its economic benefits can be realized in the first year after planting. Calliandra trees are very suitable for stakes production.

Text-box 1: Description of the Calliandra tree
Source: ICRAF

On the other hand, some solutions do exist in order to do without stakes. The first one is intercropping. The intercrop maize-climbing beans system has both yield and economic advantages over pure stands of the component species. Niringiye *et al.* (2005) showed that in Uganda greater yield advantages due to complementarity use of resources (e.g. light, water and nutrients) are realized from intercropping maize with climbing bean (Umubano and Gisenyi varieties) when maturity differences of the component species are large enough. However, control of the maize stalk borer *(Busseola fusca)* is essential to guarantee adequate support for beans. Another solution to reduce the staking constraint is the use of strings (see section 4.2.2). This solution, observed on the field, is less time-consuming and less expensive for farmers. The average price of manila strings was 53,476 KShs per hectare whereas it was 401,250 KShs per hectare for stakes. In addition, strings are less vulnerable to damages and can be used for several seasons. Hence this method is worth being demonstrated to farmers in future extension activities.

Lack of seed

The lack of seed is yet an important limitation to the dissemination of climbing beans among households in Western Kenya. It is also the main reason explaining why bush bean farmers do not grow climbers. According to farmers, the seeds given by N2Africa are not available on the local market. They obtained few seeds from N2Africa or from their neighbours; therefore they have to produce their own seeds for the next season. In this sense, many households stopped growing climbers because of the poor availability of seed (61%). Nevertheless, farmers argue that the demand for climbing beans is high, resulting in high market price. Thus there is a strong market potential for this product. A solution to the lack of seeds could be to set-up a Community-Based Seed Production (CBSP). The CBSP (also called Farmer-Led Seed Enterprise) is based on local production, selection, improvement and multiplication of seeds by farmers themselves. The purposes of a CBSP are numerous: (i) ensuring that quality seeds of locally adapted crop varieties are available to populations that need them; (ii) developing and identifying new and more productive varieties suitable to the agro-ecological region; (iii) improving the livelihood and contributing to food security (Setimela *et al.,* 2004; Karanja *et al.,* 2012). One successful CBSP project was carried out by the FAO in 2010, in Southern Sudan (FAO, 2011). It improved significantly the quality of some crop seeds and planting materials (groundnut, bean and cassava). It also significantly contributed to the reduction in seed imports, and partly addressed concerns about adaptability and aspects of seed quality. The system currently used for soybean within N2Africa is based on the same approach; farmers are given a package containing 1 Kg of soybean seeds as well as 10 g of Biofix inoculant and 2 Kg of Sympal fertilisers. Farmers have to return 2 kg of seed to the Soybean Resource Centre in order to increase the seed production and extend the program to reach new farmers. This system could also be applied to climbing beans production, the only difference being staking materials. According to master farmers, households would be more likely to adopt climbing beans, provided that they are given the package as well as *Calliandra* seeds. Collaboration with the Kenyan Forestry Research Institute and Kenya Forestry Services would be of interest.

Adoption and diffusion

Clearly, climbing beans have got a huge potential to expand its cultivation in large area. Small and scattered plots are numerous in Western Kenya; they all represent a potential cultivation area. They are mainly grown as food crop and could help to improve food security in the region. Previous research (Kwambai *et al.*, n.d.) showed that introduced climbing bean varieties were well adapted to conditions in North Western Kenya and could form high a yielding grain legume alternative to the currently grown bush bean. However at the moment, climbing bean has remained a site specific, garden crop while soybean has become a field crop well integrated into maize-based systems. It seemed clear that farmers have an insufficient access to the climbing beans technology, whether it is seed availability or knowledge diffusion. This lack of seeds seems to be specific for Africa and is often an ignored factor in crop varietal adoption studies (David et al., 2002).

A surprising result regarding the adoption of climbing beans is related to the land size. Climbing beans are often presented as the optimal solution for smallholder farmer due to their high performance on a small plot. They have a real yield advantage over bush beans. Therefore the expected results would be that small farms are more likely to adopt climbing beans. Though, the survey showed that land size is not significantly different between bush beans and climbing beans growers, the land size of climbing beans farmers is even slightly higher. Ramaekers *et al.* (2013) showed that land size positively influences the decision to adopt climbing beans meaning that larger land sizes favour adoption. When farmers adopt this crop, they rarely replace bush bean, they actually add it to their existing cropping system. This operation requires more lands and climbing bean can start competing with staple food. Therefore future promotional operators should be aware that land size could be a constraint to the adoption of climbing beans.

Also, despite the better yields of climbing bean varieties, farmers continue to grow poorly performing mixed bush bean varieties due to all the constraints mentioned previously. Hence, working with farmers to master all these constraints (e.g. lack of seeds, sufficient knowledge, staking materials, pests and diseases) seems to be a priority before considering further extension activities. In the same way, there is a need for a harmonisation of the knowledge on climbing beans production leading to a common efficient method that could be demonstrated to farmers.

Opportunities and further research

i. The role of farmer-to-farmer transmission is important both at the level of creating awareness and of testing climbing beans (Ramaekers *et al.*, 2013). Farmer-to-farmer diffusion is strong in Western Kenya, thus it could be interesting to promote it and to study its impact on climbing bean production in the region.

ii. High productivity of climbing bean varieties per unit of land gives hope for improving food security. A comparative study on yields obtained by bush beans and climbing beans can be done. Therefore, when promoting climbing beans, the actual figures of climbing beans yield could be a strong argument to convince farmers.

iii. The use of stakes is strongly influencing the performances of climbing beans. Further measurements on the final yield could be useful in order to assess the real influence of stakes on the final yield.

iv. The present study was made within the N2Africa network. N2Africa farmers are more likely to be aware of crops promoted by the project, including climbing beans. A more general survey on climbing bean adoption should be carried out to compare with the present results.

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Appendices

Appendix 1: Questionnaire form for climbing beans farmers.

Date of interview: _____/______/2013

Enumerator: _________________________

Action site (District/County/…): ___________________

Village: ______________________

Homestead coordinates (decimal degrees)

Latitude: _____________ Longitude:______________ Altitude: _____________

Introduction

Introduce yourself and the N2Africa project. Explain the purpose of the survey and assure the interviewee of the confidentiality. Please check if the farmer has any question at this time.

A. Household information

A.1.Name of respondent: ___________________________________

A.2. Total number of adults and children in the household

Adults: _________ Children (16 years or younger): __________

A.3. Gender of the household head: Male____ / Female____

A.4. Total amount of arable land available for cropping (indicate ha or acres):

____

A.5. What is the most important source of household income (please tick):

1) Cropping _____ 2) Livestock ____ 3) Trade ____

4) Off-farm income ____ 5) Remittances ____

6) Other (specify): ___________________________

B. Crop production

B.1. Please fill the table below for the main arable and plantation crops grown on the farm (exclude small vegetable gardens etc.)

Crop	Area with this crop (ha or acres)	Animal manure applied (Yes/No)?	Other organic input applied? If yes, specify type	Mineral fertiliser applied? If yes, specify type	Production used for sale (%)
Climbing bean					
Bush bean					
Cowpea					
Groundnut					
Soybean					
Other legume (specify) ___________					
Maize					
Sugarcane					
Banana					
Cassava					
Potato					
Vegetables					
Other non-legume crop (specify) ___________					

B.2. Please describe one or two typical crop rotations including climbing beans.

Rotation 1

	Principle crop	Second crop
Season 1		
Season 2		
Season 3		
Season 4		

Rotation 2

	Principle crop	Second crop
Season 1		
Season 2		
Season 3		
Season 4		

C. Climbing Beans

C.1. How many fields do you cultivate with climbing beans?

____

C.2. Where are they located within the farm? (In-field, mid-field, out-field)

____

C.3. What is the area allocated to climbing beans? (in percentage) _____ %

C.4. Since when do you grow climbing beans? ___________________

C.5. Which crop has been replaced by climbing beans? Why?

____

C.6. What are advantages of climbing bean (and compared to which crop?)

C.7. What do you consider to be disadvantages of growing climbing bean?

1) Labour intensive _____

2) Staking material _____

3) Pests and diseases _____

4) Lack of knowledge about how to grow climbing beans _____

5) Lack of seeds _____

6) Other…

C.8. In what cropping system is climbing bean included? (please tick)

1) Mono-cropping _____ 2) Intercropping ____ 3) Rotation ____

C.8.a. If intercropped, with which crops?

____

C.8.b. If rotated, with which crops?

____

C.9. Which inputs are used on climbing bean?

C.10. For what purpose do you grow climbing bean? (give percentage)

1) Household consumption ______ 2) Sale ______

D. Staking materials

D.1. What materials do you use to support your climbing beans? (please tick)

1) Sticks _____

2) Trellises _____

3) Trees _____

4) Strings _____

5) Tripod _____

6) Other (specify) __________

D.1.a. If you use stake, which species do you use?

____

D.1.b. If you use trees, which species do you use?

____

D.2. Where do you get these support materials? (please tick)

1) Grown on own field _____

2) Purchased _____

3) Fetched _____

D.2.a. If purchased, what is the price?

____

D.3. What is the life span of your staking materials / how often do you replace it?

____

D.4. Is staking a constraint for you?

1) Yes ___ 2) No ___

If yes, explain why:

D.4. Which adjustments have you done to your climbing beans field compare to what you have been demonstrated?

D.5. If you would have no financial limitations, how would be a perfect staked bean field for you?

Please, thank the respondent for her/his time. Check if the farmer has any questions at this time.

Appendix 2: Questionnaire form for bush beans farmers.

Date of interview: _____/______/2013

Enumerator: _________________________

Action site (District/County/…): ___________________

Village: ______________________

Homestead coordinates (decimal degrees)

Latitude: _____________ Longitude:______________ Altitude: _____________

Introduction

Introduce yourself and the N2Africa project. Explain the purpose of the survey and assure the interviewee of the confidentiality. Please check if the farmer has any question at this time.

A. Household information

A.1.Name of respondent: ___________________________________

A.2. Total number of adults and children in the household

Adults: _________ Children (16 years or younger):__________

A.3. Gender of the household head: Male____ / Female____

A.4. Total amount of arable land available for cropping (indicate ha or acres):

____

A.5. What is the most important source of household income (please tick):

1) Cropping _____ 2) Livestock ____ 3) Trade ____

4) Off-farm income ____ 5) Remittances ____

6) Other (specify): __________________________

B. Crop production

B.1. Please fill the table below for the main arable and plantation crops grown on the farm (exclude small vegetable gardens etc.)

Crop	Area with this crop (ha or acres)	Animal manure applied (Yes/No)?	Other organic input applied? If yes, specify type	Mineral fertiliser applied? If yes, specify type	Production used for sale (%)
Climbing bean					
Bush bean					
Cowpea					
Groundnut					
Soybean					
Other legume (specify) ___________					
Maize					
Sugarcane					
Banana					
Cassava					
Potato					
Vegetables					
Other non-legume crop (specify) ___________					

B.2. Please describe one or two typical crop rotations including beans.

Rotation 1

	Principle crop	Second crop
Season 1		

Season 2		
Season 3		
Season 4		

Rotation 2

	Principle crop	Second crop
Season 1		
Season 2		
Season 3		
Season 4		

C. Beans production

C.1. How many fields do you cultivate with beans?

____

C.2. Where are they located within the farm? (Compared to the household)

____

C.3. What is the area allocated to beans? (In percentage) _____ %

C.4. Since when do you grow beans? ________________

C.5. Have you been aware of climbing beans?

1) Yes ______ 2) No ______

C.5.a. If yes, by whom?

____

C.5.b If yes, what have you been demonstrated?

C.6. Have you ever grown climbing beans?

1) Yes ______ 2) No ______

C.6.a. **If yes**, why don't you grow climbing beans anymore?

C.6.b. **If no**, why don't you grow climbing beans?

1) Labour intensive _____

2) Staking material _____

3) Pests and diseases _____

4) Lack of knowledge about how to grow climbing beans _____

5) Lack of seeds _____

6) Other…

C.7. What do you consider to be advantages of climbing beans?

C.8. What do you consider to be disadvantages of climbing beans?

1) Labour intensive _____

2) Staking material _____

3) Pests and diseases _____

4) Lack of knowledge about how to grow climbing beans _____

5) Lack of seeds ______

6) Other…

Please, thank the respondent for her/his time. Check if the farmer has any questions at this time.

Appendix 3: Measurement form

Date:	
Place + GPS position:	
Name:	
Field 1:	
Size:	
Distance to the household:	
Cropping system:	
Staking method:	
Staking materials:	
Highest stakes:	
Average stakes:	
Lowest stakes:	
Plant spacing used (within rows):	
Plant spacing used (between rows):	
Planting density:	
Distance between stakes rows:	
Distance within stakes rows:	
Stake density:	
Number of pods:	
Number of plant per stake:	
Comments:	

Appendix 4: graph of the location within the farm.