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ASSESSMENT OF STAKING IN A CLIMBING BEAN PRODUCTION SYSTEM AS PRACTICED BY SMALLHOLDER FARMERS IN UGANDA

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Adoption of climbing bean production in Eastern Africa is faced with the challenge of finding suitable staking materials which is prerequisite for high yield potential. The objective of this study was to contribute to understanding the trends in staking and staking requirements in climbing bean production and the related ecological management practices in the Ugandan highland agro-ecosystem. Sampling was done using a four-stage sampling procedure, based on 150 households selected randomly each in Kabale and Kisoro districts. Results revealed that long term maturing trees such as eucalyptus were the most commonly used types of stakes (92.7%) in Kabale. On the other hand in Kisoro, it was stems of elephant grass (62%) followed by long term maturing trees (50.6%), shrubs mainly *vernonia* (30%) and maize plant, maize and sorghum Stover (22%). The study revealed several challenges smallholders faced with stakes and staking such as costly stakes, breaking of stakes due to heavy pod load or becoming old, theft, multiple uses of stakes (fire wood, building), termites and the cumbersome activities (cutting, transporting). However, some farmers have not perceived staking as a problem and have developed some initiatives to cope with the shortage. Further research on the sources of stakes is recommended.

Keywords: Abiotic, Agro-forestry, Climbers, Eucalyptus, indeterminate, intercropping, maize, *Phaseolus vulgaris*, stakes.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an important source of dietary protein, calories, zinc and many other essential nutrients in Uganda and other developing countries (http://www.cgiar.org/our-research/crop-factsheets/beans/; Kornegay et al., 1996). The crop is also an important source of income, particularly for resource-poor smallholder farmers and traders (Kimani et al*.,* 2005). In Uganda, common bean is traded in local, regional and international markets. Farmers in Uganda grow two types of common bean (determinate and indeterminate). The determinate types are typically known as bush beans, while the indeterminate may be semi-climbers or typical climbers. A common bean plant showing a determinate growth habit is characterized by a limited number of nodes, with flowering beginning at the apex and moving to the base. It has a terminal meristem that will switch from a vegetative to a reproductive state, thus, producing a terminal inflorescence (Repinski et al*.,* 2012).

On the other hand, indeterminate growth is characterized by stems with a terminal meristem that remain in the vegetative stage, regulating the growth

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and producing axillary inflorescences (Repinski et al., 2012). The most commonly grown are the bush types but in many parts of the world, climbers dominate highland areas where population density is high and land is limiting (Katungi et al., 2009). In Africa, some of the traditional growing areas include: Burundi, Rwanda, Democratic Republic of Congo, south-western highlands of Uganda, western highlands of Ethiopia, Kenya and Malawi (Allen and Edje, 1990; Wortmann et al., 1998). In recent years, climbers have extended to other countries like Tanzania, Angola, and Madagascar as well as expand within the traditional growing countries (Katungi et al., 2009).

In Uganda, climbing beans are grown in the highlands of Mbale, Kisoro, Kabale, Sironko and Kapchorwa districts (Opio et al*.,* 2001; Kalyebara, 2005 cited by Mwesigwa, 2009). The climbing bean technology has been adopted in southwestern Uganda mainly as a coping strategy for alarming problem of land scarcity and land degradation and to reduce food insecurity and poverty. Between 1999 and 2016 the National Agricultural Research Organization (NARO) together with other development partners introduced climbing bean to other parts of Uganda including the western highlands, Eastern and lowlands of the country. The introduction of climbing bean in those areas has been through researcher-farmer participatory approach. Since then, many more promising climbing bean lines with high yield potential, pest and disease tolerance accompanied with acceptable seed attributes for both consumption and market are in the pipe line for release.

Although climbing beans are highly accepted by farmers, their major short-coming is that they require stakes to support their growth and or should be grown in association with other crops on which they climb. Staking is a very valuable agronomic practice in climbing bean production (Lwakuba et al*.,* 2003). With provision of a strong support, staking has a positive effect on the crop by allowing the growth habit of the plant (vegetative adaptation), and results in the crop growing faster. Stakes support the weak, long and twisted stem and branches enabling reproductive adaptation (which results in pods distributed from the base to the top of the plant or production of pods for a long time), hence staking increases the yield per unit area. The virtue of a vertical position of the stake makes the crop grow upwards producing fresh healthy leaves (used as forage and vegetables) and pods giving disease free seeds. Staked beans aeration is improved which reduces the influence of pests and diseases compared to the bush beans. On the other hand when the stakes grow old they are used for fuel (fire wood).

Consequently climbing beans are considered to have the following advantages expressed in relation to staking: yield potential of two to three times higher than the bush beans (Katungi et al., 2009; Checa and Blair, 2012; Ramaekers et al., 2013), they can climb four meters high – hence ideal where space is scarce (maximize use of limited space both horizontally and vertically), conducive for piecemeal harvest practice, and by allowing a vertical growth, aeration is improved which reduces the influence of pests and diseases. Unfortunately stakes availability in Uganda and other regions is a challenge and the scarcity and poor quality stakes impact negatively on climbing bean production and farmers' livelihood (Gichangi, 2012; Gabiri, 2013). Previous studies have reported the scarcity of materials for staking as a major impediment to adoption of climbing beans (Kimani et al., 2005; Gichangi et al*.,* 2012; Rapheal, 2013; Musoni et al., 2014). And yet promoting improved climbing beans in response to the degrading environment, land shortage to alleviate food security and poverty remains crucial to meet the increasing population demand. Hence, this study was undertaken to contribute to understanding the trends in staking and staking requirements in production of climbing beans and the related ecological management practices in the Ugandan highland agro-ecosystem.

MATERIALS AND METHODS

The study area

The study area covered Kisoro and Kabale districts in southwestern highland of Uganda. The area is characterized by a bimodal rainfall pattern, sufficient for two crops per year. The two districts were purposively selected to represent the climbing bean growing areas of southwestern Uganda because climbing bean is one of the key crops in this area (Opio et al., 2001; Kalyebara, 2005; Mwesigwa, 2009 and Takusewanya, 2015). In Kisoro the farmers interviewed were from the following subcounties: Nyakinama, Nyarushiza, Nyarubuye, Muramba and Kisoro town council. Whereas in Kabale the farmers were from Kitumba, Bubare and Kamuganguzi. The region of Uganda's southwestern exhibits a good number of other common features: hilly terrain, relatively and moderate to high population density. The pattern of agricultural land use, due to high population density includes intensive farming practices. However, local climate, soil and terrain combined with farmers' traditions, preferences and markets, results in varied agricultural systems and land-use practices.

Sampling technique

The population of interest in the study constituted climbing bean growers in Kisoro and Kabale districts, where the sampling unit was the farm households. Sampling was done using a four-stage sampling procedure, based on 150 households selected randomly in each district. A four-stage sampling design purposively covered districts as the primary sampling unit, sub counties as the secondary sampling unit and villages/parishes as the third sampling unit. Within each subcounty and within the villages/parishes; the fourth

sampling unit was the climbing bean farming households. The study population consisted of both men and women farmers that are involved in climbing bean production.

Source and data requirement

Primary data were collected using a questionnaire with both open and close-ended questions. Both quantitative and qualitative data was collected. With the quantitative data numbers were used, such as price of staking material (Ug shs), Stage at which staking is done (weeks). whereas as qualitative method, data was collected from a point of view of the household practicing climbing bean production giving more in-depth information on a few cases i.e. words were used to describe the outcomes such as good or poor. Questions asked during the interviews were based on the following characteristics: 1) types of staking materials used, 2) source of staking materials, 3) price of staking material (Ug shs), 4) stage at which staking is done (weeks), 5) quality of stakes selected for use: 1. very good 2. Average 3. Poor, 6) constraints faced in staking and 7) Copping strategies used by farmers for different challenges faced with stakes and staking. During the survey, face-to-face interviews were conducted. Discussions with farmers and visual observations were also used.

Data management and analysis

Collected data was cleaned, coded and entered into Microsoft excel and then subjected to analysis using Microsoft excel and statistical package for social scientists (SPSS). Descriptive statistics (frequencies and percentages) was used for data exploration in order to identify trends and key features in the data. Chi-square test was used to test for association between the different factors and districts from which the farmers come from.

RESULTS AND DISCUSSIONS

Types of stakes used

From this survey, the most commonly used types of stakes in Kabale were from long term maturing trees such as eucalyptus (92.7%) followed by stems of elephant grass (20%). Other sources of stakes included shrubs, agro forestry trees, maize /sorghum plant /Stover support and bamboo. In Kisoro district the main source of stakes were stems of elephant grass (62%) followed by long term maturing trees (50.6%), shrubs (specifically *vernonia*) (30%), maize plant/Stovers (22%) and bamboo (13%) (Table 1). It should be noted that each farmer could use stakes of more than one type (Figure1).

In terms of the durability of staking material, our study reveals a very strong association (*Chi-square* =109.77, *df =5, p<0.001*) between the types of stake used and the district from which the farmer comes. Proportionally more farmers from Kabale use long term maturing stakes compared to Kisoro. Among the shrubs, *vernonia* was the mostly used type in Kisoro because in addition to providing stakes, it is commonly planted for controlling soil erosion, forage for mainly sheep and goats and herbal medicine for the households. *Vernonia* is normally planted in those stony places where other crops cannot be grown. Other farmers plant *vernonia* along the boundaries of their gardens.

For the case of maize /sorghum Stover as stakes, the farmers usually rotate climbing beans with maize or sorghum. At the time of harvesting, the farmers just remove the cobs and leave the maize or sorghum stalk/Stover in the garden for use as stakes for the climbing beans the following season. Those who use stems of elephant grass for staking may use it's leaves to feed cattle and the stems will be for staking climbing beans. The use of crop residue for staking was reported by earlier studies as well. Gichangi et al. (2012) reported that due to scarcity of suitable staking materials, farmers have evolved relay cropping systems of beans with maize where by stovers are used as stakes for climbing beans. Similarly Kimani et al. (2005) revealed that farmers use alternative staking material such as stalks of nappier grass, cassava and sorghum stems in western Kenya and Rwanda. Beebe et al. (2012) revealed that primitive bean varieties in Mexico, Central America, and the Andes were vigorous climbers and were planted with maize for physical support in altitudes from 1200 to 3000 masl.

Musoni et al. (2005) recommended to plant leguminous agroforestry trees like C*alliandra calothyrsus, Leucaena, Alinus,* and *Sesbania* species which regenerate and multiply faster after cutting. However, Lwakuba et al. (2003) found that *Sesbania spp.* in association with climbing beans are hosts to nematodes. Previous studies by ASARECA revealed that sisal string stakes are a good alternative, but expensive and not readily available. Banana fiber as another option is relatively cheaper in Rwanda, Congo and Burundi even though it is not as strong as sisal and wood. Poor or no staking reduces the yield of climbing beans between 30 to 100 %, depending on the variety and prevailing weather conditions (Musoni et al., 2005; Musoni et al., 2014).

The most commonly used type of staking materials were further analyzed by gender as shown in Table 2. In Kabale (52%) female-headed households used long term maturing trees such as eucalyptus for staking compared to male-headed households (40.7%). Stems of elephant grass were equally used by female (10.67 %) and male (9.33 %). Only a few male-headed used agroforestry trees (2.8%) for staking materials. None of the female-headed households used agroforestry trees for staking material. In Kisoro most women use stem of elephant grass (27.3 %). The women interviewed explained that stems of elephant grass are easy to

Table 1: Types of stakes used in climbing bean production in Kabale and Kisoro districts

	Households (%) and their type of stakes					
District	Stems of elephant grass	Long term maturing trees	Shrub	Maize /sorghum plant /Stover support	Bamboo	Agro forestry trees
Kabale	20	92.7	6	1.3	1.3	2.7
Kisoro	62	50.6	30	22	13	12.7

Chi-square =109.77, df =5, p<0.001; Long term maturing trees (Eucalyptus, *Acacia mearnsii* (black wattle); Shrubs (*venonia*, dariya, Umukondogoro); Agro forestry trees (Calliandra *calothyrsus*, Sesbania s*esban*, Leucaena *leucocephala*, cypress.

Figure 1: Staking climbing beans using (a) eucalyptus wood, (b) maize plants; (c) maize stovers ready to be used as stakes for climbing beans

Table 2: Analysis of the most commonly used type of staking material by gender among the study population

District	Type of stakes	Frequency of farmers Female/Male	Proportion (%) of farmers Female/Male
Kabale			
	Long term maturing trees	78 (61)	52 (40.7)
	Agro forestry trees	0 (4)	0 (2.8)
	Shrub	5 (4)	3.3 (2.7)
	Bamboo	2 (0)	1.3 (0)
	Maize/sorghum plant & Stover	1 (1)	0.67 (0.67)
	Stems of elephant grass	16(14)	10.7 (9.33)
Kisoro			
	Long term maturing trees	28 (48)	18.7 (32)
	Agro forestry trees	9 (10)	6 (6.7)
	Shrub	21 (24)	14 (16)
	Bamboo	9(11)	6 (7.3)
	Maize/sorghum plant & Stover	9 (7)	6 (4.7)
	Stems of elephant grass	41 (52)	27.3 (34.7)

Table 3: Staking initiation period

	Proportion of households (%) and stage/time at which staking is done			
District	1 week	2-3 weeks	3-4weeks	4-5 weeks
Kisoro	14	59	18	9
Kabale	15	62	15	8

(*chi-square = 0.65, df =3, p=0.884*).

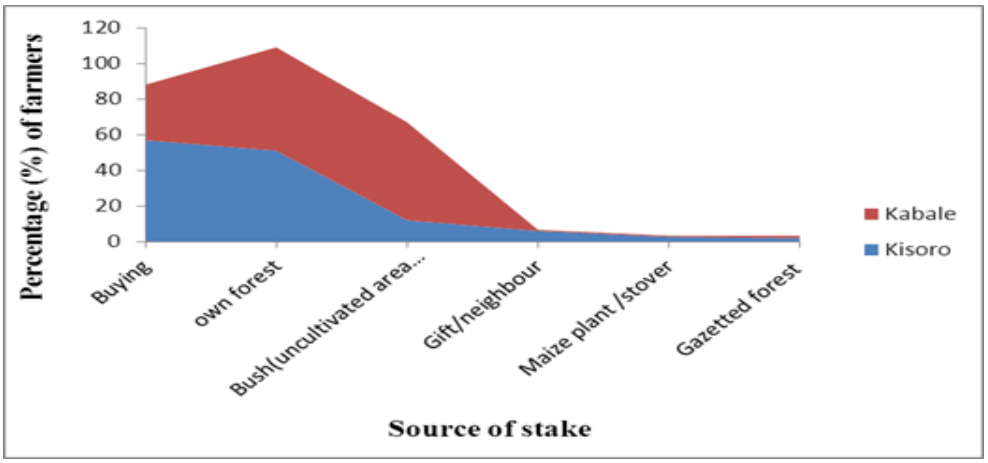

Figure 2: Source of stakes for climbing bean farmers in Kisoro and Kabale

transport and removal of the beans from the stakes at harvesting time is also easy. The stem of elephant grass can also be easily planted along the boundaries reducing on land conflicts from the men. Most women farmers reported that eucalyptus is expensive; it is mostly for the rich who can afford buying planted trees from which stakes are cut. Also it is heavy for the women farmers to use compared to the stems of elephant grass.

Stage at which staking is done

When using long term maturing trees (Eucalyptus, Acacia) and other types of staking materials, staking of beans is done at various growth stages as long as the beans have not yet started forming tendrils for climbing. Climbing beans are mainly staked at 2-3 weeks after planting, with 59 % and 62 % households in Kisoro and Kabale respectively (Table 3). Results indicated that the number of days of staking initiation of beans are not significant in the two districts (*chi-square* = 0.65, *df* =3, *p*=0.884). Staking allows beans to grow well and give high yields, of 2- 3 times higher than the bush beans per unit area of production. Staking of climbing beans is recommended to be done at two to three weeks after planting, by placing a strong stake of two meters high between two plants (NARO guide, 2003). Due to scarcity, one stake can be placed in the middle of four plants. Staking late normally results into the tendrils on climbing bean plants to twine around themselves. Eventually the crop grows crawling on the ground and getting entangled on any thing around for support. This results in pods rotting if left to grow on the ground. Staking if done late leads to additional labour for assisting the plant to climb on the stake.

The process of untwining the crop and twinning it on the stake also affects the physiological conditions of the plants which may affect the yield potential. Therefore timely staking is important to allow the climbing bean to naturally twine around the staking material by itself. Musoni et al. (2005), reported that climbing bean stems are longer, more slender, and weaker than those of bush beans and are able to twine and grow over two meters when the plant is appropriately staked. Ramaekers (2012) stated that climbing beans are morphologically distinct from bush bean varieties being characterized by tall growth, long internodes and climbing ability.

Source of stakes

Most farmers (57 %) in Kisoro buy stakes unlike in Kabale where farmers rely on their own forests and also from the bush (55 %) (Figure 2). There is a very strong association (chi-square=61.1, df =5, p<0.001) between the district where the farmers come from and the source

Table 4: Number of times stakes are used (Re-used)

	Percentage (%) of households and the number of times stakes are used			
District	1 season	2-3 seasons	4-6 seasons	7-10 seasons
Kisoro	2.7	56.7	40.7	0
Kabale	0.7	90.6	8.1	0.7

of staking material. Previous studies by Breure and Kool (2014), also indicate that majority of the farmers buy stakes from 'the car'. This car is coming from Rubanda (Kabale district, close to Kisoro district) and sell bundles of 100 stakes. This possibly explains as why different types of staking materials such as eucalyptus and stem of elephant grass are almost in the same price range per piece. The farmers reported that staking materials are expensive during the peak periods of planting. In Kisoro they are both expensive and scarce, so they use brokers to locate them. Rapheal (2013), reported that majority of the medium and rich resource endowed farmers grow and purchase staking materials.

Currently the costs range from between 100 to 500 Uganda shillings per stake depending on the type. Some households buy a plantation of trees at a price that may be determined depending on the type of trees and then cut and split them to get the required stakes. Others buy one tree at 2000 – 3000 Uganda shillings then cut and split it into stakes. On the other hand, some other households in both districts do not buy staking material as they plant their own trees. Those who own forests have reduced costs in production and timely operations of staking. According to Rapheal (2013), majority of the farmers the source of stakes is either trees grown on own fields or from the surrounding farm, while others purchase. Musoni et al. (2005) stated that the economic returns from growing climbers have encouraged farmers to invest in species like Leucaena and Calliandra to overcome staking problems, which has, at the same time, enabled farmers to exploit other values of the species, such as soil protection, soil improvement, fodder for ruminants, or a source of cooking fuel. According to Lwakuba et al. (2003), staking materials can also be obtained from wood lots, pruned hedgerows or trees grown on cropland and along field boundaries. Biggerlaar, (1994) cited by Sperling and Muyaneza (1995), indicates that 88% of the farmers obtain stakes from their own farms and as well recycle stakes efficiently.

Recycling of stakes

Majority of households in the study area recycle stakes ranging from 2-3 seasons and a few farmers use 4-6 seasons (Table 4).This observation is in line with Rapheal (2013) and Breure and Kool (2014) that stakes are recycled every 1-2 years (2-4 seasons) and sometimes every 3 years depending on the quality of staking material, soil characteristics, rainfall and storage place. While Musoni et al. (2005), revealed that stakes are re-used for up to six bean seasons.

Challenges with stakes and during staking

This study further emphasizes that farmers face several challenges with stakes and also during staking which included scarcity of staking materials, costly stakes, breaking of stakes due to heavy pod load or becoming old, theft of stakes, multiple uses of stakes (fire wood, building) and late maturing trees. In addition, staking involves cumbersome activities (cutting, splitting, sharpening and transporting stakes (due to heavy load, poor infrastructure and/ or long distances), and risks of body pain and injuries. Several studies have pointed out that scarcity of suitable materials for staking is a major impediment to adoption of climbing beans (Kimani et al*.,* 2005; Niringiye et al*.,* 2005; Rapheal, 2013; Musoni et al., 2014).

In addition, abiotic and biotic factors were important constraints in staking. Abiotic factors like strong winds, heavy rainfall make the stakes lodge hence leading to rotting and wildfires burn stakes. Further the hard nature of the ground often makes it difficult for stakes to be placed firmly in the ground and can easily dislodge after staking. Whereas the biotic factors such as termites and other pests often destroy stakes either in the field or in storage sites (Raphael, 2013). In the present study 92 % of the climbing bean farmers stated about the loss (breaking) of stakes by wind or high yields. A study by ASARECA reported that despite the better yields of climbing bean varieties in Rwanda, Burundi and DR Congo, some farmers continue to grow poor performing mixed bush beans due to lack of staking materials and sufficient knowledge on the best staking methods.

Labour scarcity was also another important constraint. Labour scarcity results from the fact that climbing beans is mainly taken as a woman crop and

Table 5: Coping mechanism for constraints in stakes and staking

Copping mechanism	% of respondents	
	Kabale	Kisoro
Using improved agronomic practices	42	45
Credit facilities	28	41
Special care/Precaution	7	17
Reduction on workload/drudgery	29	15
Use of available resources	9	7
Social Capital	10	3
Pest Control	5	1
Local council regulations	0	0.7

other family members may not take part in a number of cumbersome activities (such as cutting, carrying stakes to the field, splitting, sharpening, staking) that are often involved. Children have to meet school regulations as well and men may not be fully involved. Previous studies by Rapheal (2013) revealed relatively high labour input for staking. In most sub-Saharan countries women are primarily responsible for labour in smallholder bean production (Wortmann et al., 1998). This has a positive relationship with the findings that age being an indicator for labour by Gichangi et al. (2012), the children who are expected to have some strength go to school and Rapheal, (2013), associated it to being gender of the farm labour, notably the men go out for off farm activities.

Copping strategies used by farmers for different staking challenges

Previous studies by Takusewanya (2015) on the factors affecting productivity of climbing beans, revealed that despite the challenges in staking climbing beans, their production has several advantages compared to bush beans. Some of the major advantages include: suitability for areas with land shortage, higher yield potential hence good for food security, possess good market attributes, suitable for piecemeal harvesting and are also adaptable to local conditions. Consequently households have adopted several strategies in order to cope with the different problems experienced in staking and lack of stakes (Table 5).

Use of improved agronomic practices was the most important copping strategy used by farmers both in Kabale and Kisoro (42 and 45 % respectively). Some of the improved agronomic practices include planting early which allows to stake when the ground is soft and hence to avoid breakage, intercropping of climbing beans with other plants which provide support to the beans, use of Stover of crop plants (maize or sorghum), planting of manageable fields, using mature strong staking materials that can be recycled for a number of times in the production of climbing beans and with the ability to sustain the heavy pod load without lodging are used. Others stake their climbing beans in a slanting manner to avoid stakes lodge due to strong wind.

Staking immediately after planting also helps to avoid theft of stakes. Watering the hardest areas just before staking is practiced by farmers near water sources. In Kisoro households plant climbing beans on raised beds/ridges and staking done on raised beds avoids rotting of the stakes. Similar research findings by Gichangi, (2012) and Rapheal, (2013) indicated that relay cropping of beans with maize (where by the Stover are used as stakes for climbing beans) and intercropping system are practiced by households. However, Musoni, (2005) reported that research into appropriate staking options for climbing beans recommends the planting of leguminous agroforestry trees like *Calliandra, Leucaena, Alinus, and Sesbania* species for stakes and other uses.

With credit facilities households save money from the sales of climbing beans or borrow from local savings of farmer groups or friends to meet financial requirements for stakes and staking. Households purchase stakes and meet operational activities in staking such as hiring guards against thieves, vehicles for transportation of stakes (by the rich). Others mentioned hiring labour to supplement family labour in staking activities such as cutting, splitting, sharpening and staking.

To reduce on the work load, farmers reported various ways such as using bicycles instead of carrying stakes on the head, cutting the stakes early and allowing them to dry for a light weight to be carried to the field, or keep the stake material in the garden to avoid the bother of transporting them at home, accompanied with routine monitoring against thieves.

Special care is another important strategy that is reported in order to avoid loss and have continued

Figure 3: Illustration of piling upside down of stakes in preparation for storage after harvest

climbing bean production. Some of the measures implemented included staking immediately stakes are taken to the field to avoid theft. Some periodically monitor to ensure security of both beans and stakes or employ guards against thieves while the crop is still in the field. While others harvest and carry climbing beans up to home when still on the stakes which saves the stakes from both theft and wild fires.

Social capital was also reported as an important strategy and is in terms of farmers forming groups, others use family labour supplemented with hired labour, while others involve children. They also mentioned further that they exchange with friends or neighbours for lack of stakes, they exchange old stakes for fire wood with fresh ones for staking and may also borrow stakes from neighbours and return them after use. Previous studies by Kimani et al. (2005) revealed shared stakes, from one season to another, with friends and neighbours.

To enable longer use of the acquired stakes, households reported storing the stakes on raised beds or keeping them under shade or piling upside down (pointed ends of the stakes that were in the soil face upwards), (Figure 3). Households explained that piling the stakes upside down enables the parts of the stakes that were in the soil to face up towards the sun which allows them to dry. While in storage stakes are covered with a tarpaulin/polythene against rain, also digging trenches or diversions of water near storage place to drain water to avoid rotting. Lwakuba et al. (2003) also reported that stakes are stored away from rain for reuse in subsequent seasons.

Households also store stakes away from children to avoid damage, cleaning off soil after harvest from the stakes before storage, keep re-sharpening the used staking materials for recycling or dig a hole for the spotted most hard areas for stakes to be staked deep and firm in the soil. Stakes are also dusted with ash and smeared with used engine oil. This can be done both in the field and in storage. Others mentioned use of insecticide in storage. Pests are also prevented from invading stakes by routine checkup accompanied by frequently turning of the stakes. Local council regulations are enforced in the community in case of theft of stakes.

Conclusion

Based on the findings of this study emphasized the challenges faced by farmers with staking climbing beans. However, considering the importance of climbing beans, farmers practiced a number of strategies to cope with the challenges. There is need to continue exploring and demonstrating alternative and cheap staking materials that can easily fit the existing cropping systems in the two districts. Reintroduction and or establishment of quick maturing agroforestry trees which can be used as staking materials as well as contributing to the environment is still needed.

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