Performance of apical cuttings to fast-track production of early generation seed potato

Preliminary report

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Clockwise from top left: production of apical rooted cuttings in the screenhouse, transplanting cuttings in the field, growth during the season, harvest from a single cutting.

1. Background to potato seed systems in Sub-Saharan Africa

Addressing seed shortages for potato in Sub-Saharan Africa is a perennial challenge. In Kenya, certified seed production meets approximately 2% of effective demand[1], which has slowly increased from 0.6% in 2009. Limited access to quality seed is largely responsible for the low yields plaguing the region, 10-15 t/ha. Using quality seed is key to improving productivity of potato farming systems and has the potential to double, even triple, productivity. Considering that greater than 1 million hectares are under potato cultivation in SSA, improving productivity of potato farming systems offers opportunities to meet increasing food needs without expanding land use. Increasing productivity can be achieved without a comparable increase in land use intensity as the principal tool to close the yield gap is availing quality seed to farmers at affordable prices.

The seed potato value chain stands alone within the potato value chain. Seed potato goes through three physiologically different forms in the first three generations in the production system and seed along these generations is known as early generation seed. The first generation (G0) is the production of tissue culture (TC) plantlets in the laboratory. This is the foundation and conservation material for varieties. TC plantlets are transferred to a screenhouse to produce minitubers (G1) under protected conditions using sand hydroponics or aeroponics. Minitubers are planted in the field to produce G2 seed, which is of standard seed sizes; thereafter, seed production is about bulking tubers over a few more generations from G3 to G5. After four to five generation of field multiplication (G4 and G5), seed is certified where the practice exists. Under these systems, selling seed becomes profitable at G4 or G5 under practicing conditions.

Despite high, unmet demand for seed potato and availability of rapid multiplication technologies to produce minitubers, which resulted in increased seed production, production has stagnated, seed shortages persist and few entrepreneurs invest in seed businesses. At a planting rate of 2 t/ha combined with seed sales occurring at farm gates, expansion of seed systems is vital to ensure farmers have access to quality seed. Agro-dealers do not distribute seed potato due to bulkiness and perishability, compounding the seed challenges.

2. Integrating rooted apical cuttings into potato seed systems

Apical cuttings are an alternative to minitubers in current production systems. While minitubers are more versatile – they can be stored until ready to plant and are easy to transport, productivity of cuttings surpasses that of minitubers and the time to which seed potato of any generation is available to farmers is reduced by one season. Integrating cuttings in seed systems expands business opportunities in seed production businesses that are suitable for diverse entrepreneurial profiles (ex. MSMEs, youth groups, farmers groups, progressive farmers) through differing combinations of entry and exit points along the seed production chain. Diversification of seed production systems with cuttings could attract greater investment in seed production.

Apical cuttings in seed systems is a novel technology in Kenya. Within one year from planting the initial trial to test performance of apical cuttings in the field, two private sector enterprises, Genetic Technologies International Limited (GTIL) and Stokman Rozen Kenya (SRK), have invested in cuttings, and KALRO Tigoni seed potato unit of the National Potato Program has adopted the technology. On-going private sector investment has resulted in distributing 330,000 cuttings.

The initial trial to assess apical cuttings began in October 2015. In mid-2016, SRK and later on GTIL, invested and began production of cuttings, with the first distribution to seed multipliers in October 2016, demonstrating the fast pace the technology is developing (Box 1).

[1] Effective demand assumes that farmers purchase 25% of their seed needs each season based on surveys from the field.

Box 1. Producing potato rooted apical cuttings: Stokman Rozen Kenya

Stokman Rozen Kenya Ltd (SRK) is in the second commercial season of producing rooted potato cuttings having been involved in the trial phase with CIP as a partner.

"We are pleased at the current pace that this technology has been introduced, trialed and is fast gaining acceptance by seed producers", says Simon Ndirangu who works at SRK.

SRK has been in young plants propagation business for the past 20 years, mainly in the flower industry. Recently, the company has chosen to diversify its enterprise to contribute to food security in Kenya and has embraced potato cuttings.

"Backed by experienced staff in one of the best tissue culture laboratories in the country, we can multiply any potato variety that a client would want to produce seed from. At present, we have in-vitro plants of the following varieties readily available for cuttings production: Dutch Robjyn, Unica, Konjo, Sherekea, Kenya Mpya, Asante and Desiree. We will be introducing Shangi, Lenana, Nyota, Chulu and Wanjiku varieties soon", notes Simon

In-vitro mother plants of these varieties are grown in a restricted access net house that is designed to keep out sucking pests that can introduce viral diseases. Cuttings from the mother plants are harvested, rooted in cocopeat plugs and are generally ready for delivery to clients within four weeks having been grown under a strict hygienic environment. The growing environment and hygiene procedures serve to guarantee quality of cuttings that meet and exceed all KEPHIS requirements for production of clean healthy cuttings.

SRK will continue playing its role in supplying clean and healthy rooted cuttings to fulfil seed multipliers demand locally.

The Kenya Plant Health Inspectorate Service (KEPHIS), regulating seed certification, has endorsed cuttings and is integrating the technology into seed potato certification protocol currently being finalized. Once the modified protocol is approved by KEPHIS, cuttings will be eligible for seed merchants to use as starter material to produce certified seed.

While the production of cuttings is on its way to being established, the key step to integrating cuttings into seed systems relies on developing market demand for cuttings among seed multipliers and farmers.

3. Description of rooted apical cuttings

An apical cutting is similar to a nursery-grown seedling except that it is produced through vegetative means and does not originate from a seed. Rather than allowing TC plantlets to mature and produce minitubers in the screenhouse, cuttings are produced from the plantlets in the screenhouse by taking single or double node cuts from lateral shoots. Maintaining the juvenile stage of the mother plants is key to retaining productivity, whereby the mother plant remains in a state with simple leaves (Fig 1). The first rounds of cuttings expand parent material in the first months of production with the remaining months dedicated to commercial production (Fig 2). In Vietnam, commercial growers achieve approximate ratios of one TC plantlet producing 250 cuttings using the system of bulking parent material prior to commercial production.

Once rooted and hardened, cuttings are planted in the field to produce the first round of field seed tubers, followed by one to three successive generations of field multiplication. With high rates of productivity, 8-10 and up to15+ tubers per cutting, cuttings can be profitable after two seasons of multiplication resulting in farmers accessing seed, equivalent to basic seed (G3) in seed certification systems. With seed being available for farmers after two to three field generations of multiplication, seed tubers produced from cuttings are high quality planting material and can be multiplied on-farm for a

further few seasons without risk of significant seed degeneration, provided good agricultural practices are followed.

Figure 1. Mother plants from tissue culture to produce apical rooted cuttings. The juvenile stage of the plants maintained by keeping plants at simple leaf stage. Note multiple shoots starting to form giving rise to exponential growth in production.

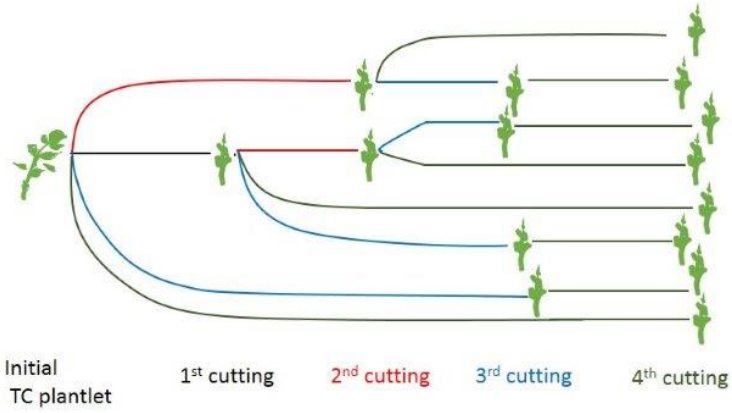

Figure 2. Propagation of mother plants. The diagram is simplified assuming a linear propagation rate with each mother plant giving rise to one shoot at a time. In reality, after cutting the apical tip form the cutting, each mother plant provides 1 to 3 shoots for cutting.

4. Apical cutting versus stem cutting

Apical cuttings originate from tissue culture material, ie the mother plant is maintained in a juvenile state throughout the production cycle. The high productivity potential is in the physiologically young tissue retained in a simple leaf stage which results in the high productivity per apical cutting, 8-10 tubers/and up to 15+, cuttings per plant.

Stem cuttings generally implies that the mother plant has developed compound leaves, physiologically older. Normally mother plants for stem cuttings originate from a tuber, develop compound leaves, and sprouts and shoots are taken as cuttings. Stem cuttings originating from mother plants with compound leaves generally yield 1-2 tubers per stem.

5. Productivity of cuttings in the field

Progressive farmers and seed multipliers have hosted two trials over two seasons, with a third season is

in progress, to assess productivity of cuttings in the field under farmer conditions (Table 1). The seed multiplier receives the cuttings in exchange for providing labour to produce the seed crop. Thereafter, CIP retains a percentage of the production (approximately 25%), and the seed multiplier manages the balance. The cuttings of different varieties were planted in beds of 0.5 and 0.6 m wide at 15 x 20 and 20 x 25 cm, respectively, resulting in approximately 150,000 and 100,000 cuttings per hectare, respectively.

Table 1. Trial sites to assess productivity of apical cuttings conducted in collaboration with progressive farmers and seed multipliers in Kenya

Season	County	Host Farmer	GPS coordinates		Altitude (masl)
Season 1 Oct 2016 to Feb 2017	Uasin Gishu	Joseph Kwambai	0.303524	35.449351	2,315
	Uasin Gishu	Isaiah Kemei	0.243197	35.48423	2,498
	Uasin Gishu	Kibinge Wainaina	0.219914	35.441163	2,404
	Uasin Gishu	Joseph Kwambai	0.303524	35.449351	2,315
	Nandi	Sammy Sugut	0.19639	35.286937	2,092
Season 2 April to Aug 2017	Uasin Gishu	Gilbert Langat	0.493462	35.420218	2,292
	Uasin Gishu	Geoffry Bii	0.528973	35.206938	2,014
	Nandi	Isaac Tallam	0.173724	35.114493	1,977
Season 3 October 2017 to March 2018	Uasin Gishu	Billy Kosgei	0.492575	35.42087	2,282
	Elgeyo-Marakwet	Paul Kibowen (Kapchelanga SHG)	1.03468	35.47332	2,864
	Elgeyo-Marakwet	Josephina Kibet (Culture Women Group)	1.07084	35.461957	2,761

5.1 Evaluation criteria

The first round of multiplication in the field whether it be from minitubers or cuttings is assessed by tuber number rather than tuber weight. The first round is never intended for sale, making number a better measure of yield rather than weight as all seed is expected to be planted at the same rate the following generation of multiplication. Tubers greater than 20 mm are to be planted in the field the following multiplication, while those less than 20 mm are to be planted in a nursery bed. The target yield is 8 tubers > 20 mm/plant.

5.2 Trial Results

Season 1

While the results were highly variable, this was the first time after one on-station trial to assess productivity, they were promising mostly achieving the expected multiplication rate of 8 tubers/cutting (Table 2). Productivity was overall greater at the larger spacing of 20 x 25 cm compared to 15 x 25 cm.

Table 2. Season 1 assessment of productivity of apical cuttings to produce seed potato tubers

Variety	Spacing	Mean (range) # tubers/cutting [a]	Mean (range) # tubers > 20 mm/cutting
Dutch Robyjin	20 X 25	15.7	9.4
Shangi	20 X 25	10.4 (8.7-12.6)	7.2 (5.2 to 9.1)
Konjo	20 X 25	8.7	7.3
Unica	20 X 25	8.4 (6.5-9.5)	7.0 (4.6-8.2)
Shangi	15 X 25	9.1 (4.4-11.9)	6.1 (2.6-8.7)

Unica	15 X 25	5.7	4.6 (4.0-5.2)

[a] Range provided where relevant

Season 2

Productivity improved from season 1 to season 2, with mean tuber numbers surpassing the expected target of 8 tubers/cutting, with mean tuber greater than 20 mm averaging 8.8 to 15.6 (Table 3). Generally, productivity increased as spacing increased for all varieties.

Table 3. Season 2 assessment of productivity of apical cuttings to produce seed potato tubers

Variety/spacing	Mean # tubers/cutting	Mean # tubers > 20 mm/cutting
Dutch Robyjin	**12.0**	**10.4**
15X20	10.7	8.6
20X25	9.3	8.0
75X30	16.1	14.6
Tigoni	**17.0**	**15.6**
15X20	13.4	11.8
20X25	15.2	13.9
75X30	22.4	21.1
Unica	**9.5**	**8.8**
15X20	7.7	7.3
20X25	8.2	7.7
75X30	12.5	11.6

Productivity obtained by seed multipliers

Additionally, the project partner Farm Input Promotions Africa is supporting 40 seed multipliers to produce seed potato from cuttings under an informal seed system approach. In the first season of production, seed multiplier yields surpassed the expected 8 tubers/plant, however only total tuber number data was provided, data disaggregating size was not collected (Table 4).

Table 4. Productivity seed potato tubers from apical cuttings obtained by informal seed multipliers in their first season of production

	Mean number of tubers/cutting			
Variety	**Kibiricha network**	**Kiirua network**	**Nkuene network**	**Abothoguchi network**
Tigoni	11.9	8.3	11.1	9.1
Unica	22.9	18.4	-	8.3
Konjo	25.5	24.1	13.9	-
Dutch Robyn	13.0	9.1	-	-

Way forward to developing and scaling out apical cuttings

Key to the success of this technology is building market demand for cuttings, which relies on diversifying end-uses. Currently the technology targets seed multipliers, but expanding to ware farmers who practice saving seed on-farm will increase opportunities for private sector to invest in producing cuttings. Investing in rooted cuttings for seed production could be interesting for youth as little land is required, and profit margins are high when producing seed from cuttings. Youth could even embark on businesses to produce cuttings. There further remains technical and economic questions to produce

cuttings to determine unit price which is currently estimated at US$ 0.10 to 0.15/cutting. Specific questions regarding productivity of successive cuttings of mother plants and those for production still persist.

Specific topics to address knowledge gaps to enable the cuttings technology to integrate into seed systems and follow the impact pathway (Fig. 3):

- build awareness of the benefits of integrating rooted apical cuttings into seed and ware potato production systems,
- develop diverse markets to produce cuttings and use cuttings for seed production, and
- develop business models along seed potato value chains considering the diverse combinations of entry and exit points that target diverse profiles of entrepreneurs (MSMEs, youth, farmer groups, progressive farmers).

Figure 3. Impact pathway for apical cuttings