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Delivering new technologies to the Tanzanian sweetpotato crop through its informal seed system

The concept of integrated seed sector development (ISSD) for sweetpotato was tested in Shinyanga and Meatu districts of the Lake Zone of Tanzania. Agricultural Research Institute (ARI)–Ukiriguru documented the informal system. It comprised male and female vine multipliers with land close to water sources growing sweetpotato during the dry season. They sold vines during the rainy season, with male multipliers and those with larger crops selling more. The average multiplier supplied ~50 farmers who commonly travelled 20km, each buying ~1-2 bundles of vine and provided an entry point for disseminating technologies. ARI–Ukiriguru organised demonstrations of rapid multiplication, inorganic and organic fertilizers and new cultivars on multipliers' land. Fertilizer could economically more than double vine yields with huge potential benefits for an area where production is constrained by planting material; some multipliers immediately began using it. Multipliers took rapid multiplication and new cultivars to their home gardens for further experimentation, seeming *likely to adopt especially the cultivar NASPOT 1. A strategy of growing large quantities of irrigated sweetpotato in Misungwi and selling the vines long-distance in Shinyanga, a marketing strategy derived from Uganda, was also adopted. These successes confirm the value of formal-informal seed sector interactions in ISSD.*

Key words: Integrated seed sector development; Marketing; Planting material; New varieties; Sustainability.

Running title: Disseminating technologies through an informal seed system

INTRODUCTION

Seed systems lie at the heart of agriculture. Despite this, most seed of most crops in developing countries is provided by the informal sector (Minot et al. 2007; Louwaars and de Boef 2012; McGuire and Sperling 2013). In particular, there is little commercial interest in seed of vegetatively propagated crops (Traoré and Seck, 2011) (The term 'seed' is used here in its wider non-botanical meaning to mean that which is planted). Even for relatively commercial potatoes (*Solanum tuberosum* L.), >99% of Kenyan farmers source their seed from informal seed growers (Gildemacher et al. 2009). There has been a proliferation of seed projects (Sperling and McGuire 2012) but often the seed is given (seed aid) (Sperling et al. 2008), few such projects using a sustainable mechanism even to deliver the seed to farmers (Jones et al. 2002; Sperling et al. 2004; Gibson 2013). Those that do usually rely on formal agro-dealers who are largely unresponsive to customer needs and are uncompetitive (Sperling and McGuire 2012); both the abilities of commercial seed systems and the inabilities of informal seed systems to provide farmers with seed tend to be exaggerated by aid organisations (Remington et al. 2002). Direct-to-farmers seed aid projects attract donor support through familiarity, even though modifications including vouchers, seed fairs (Remington et al. 2002) and small, often subsidized (Chirwa and Aggarwal 2005) starter packs of seeds (David and Sperling 1999) are more efficient (Makokha et al. 2004) and supportive to local traders (Walsh et al. 2004). Even so, seed aid can provide the wrong cultivar, distort seed markets, hinder resilience and create dependency (Sperling and McGuire 2010) and, if a new variety is given to farmers, they can easily lose it during the off-season (David et al. 2005). Aid organisations usually present farmers as needy individuals or communities requiring training in seed multiplication or other support (Tripp 1995; Barker et al. 2009). By contrast, Almekinders et al. (1994) asks that: “local seed systems are recognized as rational systems, complementary to the formal ones”, describing how they can be strengthened through linkages with formal seed systems. Thiele (1999) also emphasises their complementarities, these ideas leading to the integrated seed sector development (ISSD) concept (Louwaars and de Boef 2012). Consistent with this, informal individual bean multipliers and traders are better at distributing the seed of improved bean (*Phaseolus vulgaris* L.) cultivars than NGO-trained farmer groups (Otsyula et al. 2004).

Sweetpotato, *Ipomoea batatas* (L.) Lam., is a crop widely grown in the tropics for its starchy roots. It is clonally propagated through cuttings: varieties consequently remain trueto-type. Tanzania has the second biggest production (3.0 x 10^6MT) in Africa after Nigeria (3.4 x 10^6MT). Sweetpotato is the third largest crop by weight (FAOSTAT 2014) and the Great Lakes region is a major area of production where, as throughout Africa, the crop is especially important to smallholders (Kapinga et al. 1995). There is a very long dry season there, crops being harvested as they reach maturity and to avoid loss through desiccation and weevil damage, so most farmers have no vines to plant when the rains come. Consequently, insufficient quality planting material at the start of the rainy season is a prime constraint on production there (Kapinga et al. 1995; Namanda et al. 2011) as in many African countries (Barker et al. 2009; Gibson et al. 2009). In the informal seed system of sweetpotato, farmers with access to wetlands or land that can be irrigated and the 'skills, talent and gumption' (Guéi et al. 2011) maintain crops through the dry season (Gibson et al. 2009; Gibson 2013) and sell the vines to other farmers as planting material during the rainy season (Gibson et al. 2009; Namanda et al. 2011), acting as the informal seed supply system.

This system fails to provide the quantities of planting material required in the Lake Zone so food production is inadequate. However, it could provide much more if improved by various technological innovations available through the formal system. Nitrogenous fertilizer has long been known to increase vine production (Johnson and Ware 1948) and a rapid multiplication technique (RMT) for vines has been developed (Benesi et al. 1998; Stathers et al. 2005), though neither is widely used in Africa. High yielding cultivars of white-fleshed sweetpotato (WFSP) such as NASPOT 1 (Mwanga et al. 2003) and orange-fleshed sweetpotato (OFSP) such as Kakamega (Mwanga et al. 2007) with high β-carotene to combat vitamin A deficiency (Low et al. 2007) have also recently been released in Tanzania. Promoting such changes through interventions aimed at multipliers would require fewer resources, be self-maintaining and more sustainable than interventions aimed at sweetpotato farmers in general. It would also be consistent with the ISSD approach.

The purpose of this paper is to describe the range and capacity of the informal sweetpotato seed system to supply vines sustainably to large numbers of farmers in Shinyanga and Meatu districts of the Lake Zone of Tanzania and then to document how the formal sector can supply improvements to it, using small demonstration trials to introduce improved technologies such as:

- fertilizer to boost vine production;
- modern cultivars including OFSP;
- RMT including more efficient irrigation.

Furthermore, the paper assesses transporting vines from an area where they are easy to grow to sell them in Shinyanga and nearby markets. This longer-distance marketing is a strategy learnt from Uganda (Rachkara et al. 2015), can supplement vines from local multipliers' farms and provide a more comprehensive service. In documenting outcomes, this paper serves as one of the first evidence-based demonstrations that the ISSD approach can deliver improvements efficiently to the informal sector. In this case, delivery of the technologies was by members of a Tanzanian government agricultural research institute, the Agricultural Research Institute (ARI)–Ukiriguru, part of the Lake Zone Agricultural Research and Development Institute (LZARDI). The work is an outcome of many years of experiences by the authors and their institutes to develop a successful strategy for interacting with the sweetpotato vine supply system in order to achieve lasting improvements.

MATERIALS & METHODS

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Shinyanga and Meatu districts are located in the Simiyu Region of the Lake Zone; they are away from Lake Victoria (Fig 1) and have a particularly harsh and long dry season. The seasonal rivers Manonga and Sibiti, along which many multipliers have their farms, form the southern border of Shinyanga and Meatu respectively. Mwanza, the main city in the Zone and the second biggest in Tanzania, is ~170 km north of Shinyanga. The tarmac trunk road, the B6, connects Mwanza to Shinyanga and then continues southeast, intersecting with the B3 trunk road to Dodoma, the capital of Tanzania, and to Dar es Salaam, the main business centre and the largest city of Tanzania. Meatu district is to the east of Shinyanga and is served by only unsealed 'murram' roads. A gulf from Lake Victoria runs alongside the B6 for the first 50 km from Mwanza. Misungwi (Mwanza Region) is located at its end and here many farmers grow horticultural crops using the permanent water supply of Lake Victoria to irrigate their abundant flat and low-lying land. They export the harvest via the B6. ARI-Ukiriguru also lies along the B6, roughly midway between Misungwi and Mwanza. In Shinyanga and Meatu districts, the long dry season, generally with no rain occurring, lasts from around the middle of May to October/November. This dry season is too long for sweetpotato crops to span; they have to be harvested as they reach maturity and to avoid losses from desiccation and weevils. Consequently, the planting material, vines, is lost. This dry season is followed by the short rains lasting till mid-January, usually comprising occasional but heavy downpours. During this period most farmers buy vines from those very few farmers (vine multipliers) who have land that can be watered during the dry season and so maintain a crop. There is then a short dry spell till late February followed by the long rains (the main cropping season) till mid-May, usually comprising less heavy but more frequent and reliable rainfall. Then the cycle restarts.

Information on the sweetpotato vine multipliers and how the seed supply chain operates was gained by interviews with multipliers structured by a checklist including a crop

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calendar, land and labour usage, and the main issues associated with producing vines. Frequent contacts with multipliers and their environment were maintained through:

- one author being employed in Shinyanga in 2013;
- two authors being employed at ARI-Ukiriguru, close to Misungwi;
- all authors making visits to the demonstration sites which included unstructured interviews with multipliers.

In both districts, informal sweetpotato vine multipliers representing different areas and types of production were identified in 2013 with the aid of district agricultural officers; 34 were selected, eight in Meatu District and 26 in Shinyanga District, where more multipliers seemed to be located. In addition, a multiplier in Misungwi, Mr Maguta, was selected because he seemed entrepreneurial and his fields were extensive, easily irrigated from Lake Victoria, and close to the B6 road. This made him strategically located to supply vines to farmers in Shinyanga where the authors suggested he might make money by taking vines to markets. All the vine multipliers had been selling vines for many years as informal entrepreneurs. All were given data sheets and asked to record carefully cash sales, gifts/ bartering (vines were also sometimes given in the expectation of a future reward) and their own use of the vines.

Nine of the multipliers in Misungwi (1), Meatu (3) and Shinyanga (5) districts agreed to each host a single replicate demonstration trial in 2013 comprising four rates of NPK (20:10:10) fertilizer applied at the equivalent of 0, 50, 150 and 250kg of N/ha) x three cultivars (a locally popular check landrace which varied amongst the trials and two nationally released varieties, Kakamega (OFSP) and NASPOT 1). The 0kg of N represented local practice. A general RMT management practice of planting ‘on the flat’ as recommended for vine multiplication (Benesi et al., 1998; Stathers et al., 2005) was used throughout but using 20cm long vines at 20 x 10cm spacing rather than the recommended short 2-node cuttings because the longer cuttings did not require daily watering. Plots had raised edges to allow watering without waste, also avoiding transfer of fertilizer. Each plot measured 1 x 2.4m. Each demonstration trial was located in lowland fields that the multipliers used for vine multiplication during the dry season. They were planted in August towards the end of the dry main season as done normally by multipliers during the second phase of multiplication of vines (Fig 2). The multipliers failed to maintain watering at two trials and the trials were abandoned. At the remaining 7 trials, the numbers of vines at least 30cm long harvested in the central half (1.2m^2) of each plot were harvested and recorded three times, at 45 days after planting and then twice more at intervals of 3 weeks. Any roots produced were not recorded; RMT is designed to promote vine production and not root production. In August 2014, an identical layout and variety treatments were used but fertilizer treatments were changed to the equivalent per hectare of 1) 10t of farmyard manure (FYM) from a cow and goat stockyard, 2) 5t of FYM + 50kg N/ha of NPK (20:10:10) fertilizer, 3) 150kg N/ha of NPK fertilizer, and 4) a nil treatment representing local practice. RMT was again used as a general management practice applied throughout. The single replicate trials were conducted in lowland fields at 12 locations, one in Misungwi district, 3 in Meatu district and 8 in Shinyanga district. Again, the numbers of 30cm vines generated by 3 cuts of the central 1.2m^2 area of each plot were recorded. In both trials, the benefits of the fertilizers were calculated using the 2013 cost of NPK fertilizer and the values of vines obtained from multipliers' sales in 2013. The costs of obtaining and applying the fertilizer and the FYM were ignored because they were likely to be 'in-house', low and difficult to obtain, even of approximate values.

Nine demonstrations, each consisting of a single replicate of 7 plots, 6 of which were planted with released cultivars and one with a local cultivar control, were planted in upland multipliers' fields in November or December of 2013, so that the crops became established during the short rains, survived the short dry season and then grew to maturity in the long rains, the normal farming practice (Fig 2). Each plot was 4 x 6m consisting of 4 ridges, each of 20 plants at 30cm spacing. The released cultivars, publically available to all, were the WFSP Tanzanian cvs Simama and Polista, the WFSP Ugandan cv. NASPOT 1, the OFSP Kenyan cv. Kakamega and the OFSP Ugandan cvs Ejumula and cv. NASPOT 10 (Kabode). Farmer meetings at the demonstration sites were held during the growing season and at harvest; root yields in the central two rows in each plot were assessed.

The data on the multipliers (Tables 2-3) were analysed using statistical formulae (means, standard deviations, standard errors, Student’s t test, Chi-Squared test) in Microsoft Excel 2010; the numbers of vines harvested from the fertilizer x variety demonstration trials were analysed using Genstat version 14. Prices are given in Tanzanian Shillings (/-); 1,605/- was equivalent to one US Dollar in October 2013.

RESULTS

General observations on the informal seed system.

Most of the smallholder farmers in Shinyanga and Meatu districts could not maintain sweetpotato crops during the long dry season (May–November) because they lacked water for irrigation. As a result, they had no vines to plant when the rains came. Multipliers, by contrast, had access to water for irrigation, though usually with difficulty and from wells in dried-up beds of seasonal rivers. These few (perhaps ≤0.1% of farming households) planted small areas of sweetpotato in June (Fig 2) at the start of the dry season in low-lying areas where they could irrigate them, usually by hand. The areas were expanded further in August-September. In November, once the short rains started, the multipliers gradually established

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their crops in upland areas, initially using vines from the crops planted in June. They also started selling vines to farmers; this increased in late December-January as their later planted crops also started producing mature vines. By the start of the main rains (late February), the multipliers no longer had a monopoly for vines as the crops planted by farmers in January were sufficiently mature to be ‘pruned’ for cuttings and vines could also be obtained from sprouted unharvested roots growing in old fields (Gibson et al. 2009; Namanda et al. 2011). Crops planted in late December and January started yielding roots in April; those planted in March matured in June and July, relying on residual moisture in the soil in these latter months (Fig 2).

Detailed data collection from multipliers.

Nineteen male and 16 female multipliers were studied (Table 1). Most (15) of the men owned their land and 4 rented; in comparison, only 7 of the women owned the land and 9 rented ($P<0.05$). Similarly, of the 12 growing >0.25ha of sweetpotato for vine production, all were men; those growing <0.25ha comprised all the 16 women and the remaining 7 men ($P<0.001$). Of those growing >0.25ha, all 12 were owners; of those growing <0.25ha, 11 were owners and 12 rented ($P<0.01$), 4 of the men (60%) and 7 of the women (40%) owning the land.

The multipliers used a diversity of water sources during the dry season. Ten of the 35 original vine multipliers surveyed failed to keep their crop because their source of water dried up. Those who succeeded used the gulf from Lake Victoria (1), natural springs (2) or wells in a river bed (14). Those with a well a long way from a river bed had 60% success (3 of 5) ($P<0.05$), those using a well in the flood plain had only 43% success (6 of 14) ($P<0.001$), the wells tending to dry out. It was also mainly men who failed - 9 men failed but only one woman ($P<0.01$). Having a pump also didn’t guarantee success; indeed, 15 had a pump and

18 carried water but 8 of those with a pump failed because the water ran out, perhaps exhausting it by over-use and initial over-optimism of the carrying capacity of their wells, whereas only 2 of those carrying water failed (P<0.01).

Despite their differences, all multipliers kept about the same amount of vines for their own use (Table 2), male multipliers keeping 10.1±0.9 bundles and female multipliers keeping 9.6±0.7 bundles, and ones with ≥0.25ha keeping 11.9±2.6 bundles and ones with <0.25ha keeping 9.6±0.7 bundles for their own use. Each bundle contained about 300 vines, each vine being up to 1m length and providing two or three cuttings, so each bundle planted about 0.03ha. The multipliers tended to plant their own fields before selling or giving to customers and often initially reserved a part of their vine crop for themselves. In this way, they established crops early in the rainy season and sold the roots early in the season when the price was high and could also perhaps sell the vines from that crop. They also all gave / bartered (for a chicken, other food etc) similar amounts of vines, male multipliers giving 5.1±0.6 bundles and female multipliers giving 4.4±0.5 bundles, and ones with ≥0.25ha giving 6.0±4.9 bundles and ones with <0.25ha giving 4.5±0.4 bundles. Interestingly, the male multipliers gave vines to 7.4±1.4 beneficiaries whilst the female multipliers gave vines to only 5.4±0.8 beneficiaries and the ones with ≥0.25ha gave vines to 7.3±6.4 beneficiaries and the ones with <0.25ha gave vines to 5.4±0.8 customers. The vines were given away mostly to relatives but, even with these, there was apparently often something in kind given in return.

The big differences between the multipliers with different areas of land planted to vine production were in the number of bundles of vines they sold and the amount of money they made, each bundle usually selling at around 5000/-, or roughly $US3. The multiplier with >0.5ha of sweetpotato, Mr Maguta, was in a class of his own, pumping water from the effectively inexhaustible Lake Victoria (Table 2). He sold 364.5 bundles to 217 buyers, making 1,822,500/-, those with 0.25-0.5ha each sold 121±103 bundles to 60±53 customers, making 603,300±515,500/-, whereas those with <0.25ha sold 61±6 bundles to 37±3 customers, making 306,400±26,600/-. Since women mostly grew smaller areas of vines than men, this meant that women sold only 60±6 bundles of vines to 36±4 customers, making only 302,500±30,700/- whilst men sold 128±12 bundles of vines to 72±8 customers, making 642,000±58,200/-. They also tended to sell for different reasons: women tended to grow vines to sell for family needs, like for example Rebeka Mbonje (Fig 3), whilst men sold to satisfy farming needs, like for example James Kamuga and Sebastian Maguta (Figs 4 & 5). All categories sold similar amounts (one or two bundles) to each customer (Table 2). Most customers came only once this season; a few came more than once but, on the other hand, some, especially those from further away, may also have been buying on the behalf of others and it probably averaged out that the number of transactions recorded was roughly the number of farmers supplied. There were torrential rains in parts of Meatu during the latter part of the short rains, rivers flooded, and several multipliers who had their multiplication plots close by (those who had had their well in the river channel) lost much of their crop. Nevertheless, they all sold a large number of bundles, flooding occurring too late to affect sales much (Table 3).

All but Mr Maguta sold mostly to farmers within 20km radius (Table 3). The customers apart from some of Mr Maguta's all came to the multiplier's field when buying; there they also often harvested the vines themselves and they bore the cost of packing and transportation back home. They often came on bicycles, using the bicycle to carry the cuttings home. The customers seemed to be fairly evenly divided between men and women, though this wasn't analysed. Although Mr Maguta (Fig 5) started selling vines in the usual way, with customers coming to his field to buy vines, with the advice of the authors', he also took vines experimentally to markets. These markets included his home town of Misungwi, nearby Ngudu and Hungumalwa, and to Nyasamba and Mwadui near Shinyanga. He sometimes took them with his tomatoes which he also grew and on lorries returning empty from Mwanza to Dar es Salaam. He was surprised how well they sold in the markets; 153 bundles were sold to 103 customers. This was the first time he or any other multiplier studied had taken vines to the customer instead of the customer coming to the field of vines. Mr Maguta is planning to plant three times as much sweetpotato for selling vines next year; some neighbouring multipliers who had seen his success were also seen to be multiplying large areas of vines in 2014 and had begun selling large quantities of vines by November.

Fertilizer demonstration trials

The multipliers had never before used fertilizer (and seldom used manure either) on sweetpotato for vine production so they were surprised by the excellent response (Table 4). In both years, the yields of vines of the three cultivars and their interaction with fertilizer were similar ($P>0.05$) so average yields of the three are presented. The response to inorganic fertilizer was greatest at the 50kg of N/ha rate but remained excellent up to 150kg of N/ha, diminishing (but remaining positive) at the 250kg of N/ha rate (Table 4a). Rates of return were also high, being 30-fold the cost of the fertilizer at the 50kg of N/ha rate, with no other obvious costs being incurred except maybe a little more water because of the increased canopy. In the second trial (Table 4b), 5t/ha of FYM + 50kg of N/ha doubled the yield of vines, nearly equalling the yield of plots treated with 150kg of N/ha and far exceeding the yield of 50kg of N/ha in the previous year. Despite this, even 10t/ha of FYM only boosted yield a little, suggesting a synergy of the inorganic and organic fertiliser. There was negligible yield of roots because the crop was grown under RMT.

Other multipliers visited the demonstration sites. Many were observed to have started using inorganic fertilizer during the dry season of 2014. Rebeka (Fig 3) and several other small-scale multipliers pointed out that an advantage of fertilizer for them was that it increased production without apparently using more water. They shared water supplies with the community and use of water was primarily for humans, secondarily for animals and only thirdly for crops. It was thus socially acceptable to increase production using fertilizer but not by increasing the area which would automatically increase water use.

Variety demonstrations

NASPOT 1 had the greatest yield in the variety trials but the main purpose of these trials was to encourage multipliers in particular to observe the different varieties and to take planting material of new cultivars back to their home gardens to try for themselves. This was achieved; casual observations made during the subsequent dry season revealed that these cultivars were being grown in their conservation and subsequent multiplication plots during 2014, but especially of NASPOT 1 and also NASPOT 11 and Polista. Small quantities were usually grown but large areas were occasionally found (Fig 6). Many bundles of vines of NASPOT 1 were sold; customers some of who had seen the variety growing in the demonstrations had seen its canopy quickly covered the soil and it was resistant to SPVD.

DISCUSSION

Sweetpotato is one of the main crops in Shinyanga and Meatu districts; the main constraint is the lack of vines as planting material (Barker et al. 2009; Gibson et al. 2009; Namanda et al. 2011). At the start of the rains in November and December, this shortage is acute and this paper describes how the informal sweetpotato seed system in Shinyanga and

Meatu districts in the Lake Zone of Tanzania can be improved to at least partially satisfy this need. The system comprises multipliers who own or hire the very limited land in the area that can be irrigated during the dry season. These multipliers maintain crops in these areas and make a business of selling planting material during the rainy season. The multipliers were diverse, being men and women, growing different amounts of vines, watered from different sources and by different means. However, they all sold on-farm direct to farmers who mostly came from ≤20 km to cut and purchase the vines during the short rains and at the start of the long rains. In this way, customers could select disease-free planting material (Gibson et al. 2000), had the benefit of judging the quality of the planting material and, by purchasing, ensured the system is sustained year after year. Bartering and mutual aid still occurred but, as with most crops (McGuire 2008), selling was the norm. A multiplier commonly supplied 1-2 bundles of vines to each of ~50 customers in 2013. We do not know exactly how many multipliers exist in Shinyanga and Meatu districts but estimate a minimum of 150, indicating around 7,500 customers were supplied in these two districts alone each year. Many times this number must be supplied in the whole of the Lake Zone, let alone Tanzania.

Currently, this system supplies insufficient planting material for farmers, limiting production. Indeed, multipliers told us in interviews that quantities could be doubled or quadrupled without satisfying the demand. The very large production (and financial) gains to be made by applying fertilizer, both in the form of FYM and inorganic fertilizer, to vine crops were therefore quickly being adopted. FYM had little effect by itself but appeared to act synergistically with inorganic fertilizer, possibly by improving the soil structure. As a result, as little at 50kg of N/ha combined with FYM could double the yield of vines and, as lack of vines to plant was the main constraint, potentially doubling the production of the main crop, with consequent huge impacts on the food supplies in the area. The fertiliser incurred little extra cost apart from its purchase whereas the main cost of the FYM was probably carting it to the field. However, labour costs during the dry season were hard to assess: it would mainly be family labour and there was little else that could be done profitably then. Multipliers already used fertilizer on other crops and using it on sweetpotato seemed to be a 'game-changer', enabling the vine crop to be similarly attractive as tomatoes, the other crop commonly grown in the dry season under irrigation. Selling vines is safer than selling tomatoes and appeared similarly profitable when fertilizer is used though the evidence was only anecdotal (Fig 4). There are also no sprays applied, harvesting, packing, transporting are done by the customer and the crop isn't harvested till it is sold so it can't perish when the crop is bought on-farm, its roots can be eaten or sold when there is little food about and prices are high, and it also provides vines for the multiplier to plant an early crop for roots to sell at a season when food is still scarce so the price is still high (Hall et al. 1998). During monitoring visits in 2014, several multipliers were seen to have used fertilizer *and* increased their area of production in 2014, leading to a likely large increase in the supply of vines. Where water was limited and a communal resource, compost and fertilizer were also a socially acceptable way of increasing vine production, like for example by Rebeka Mbonje (Fig 3) and other small multipliers.

Variety demonstrations with multipliers during the main production cropping period successfully introduced new cultivars to the multipliers' lowland (dry season) gardens; NASPOT 1 was especially preferred but it was too early (Jones et al. 2002) to predict which cultivars will ultimately be adopted. NASPOT 1 is well known as a very high yielding variety (Mwanga et al. 2003) and its adoption would also be likely to improve the food availability in the districts. Other outstanding varieties from Uganda including NASPOT 11 and New Dimbuka; the OFSP NASPOT 12 and 13 are entering the release system in the Lake Zone and are also likely to benefit the food and micronutrient status of the area. With this better understanding of the informal system, the formal one, for example, ARI-Ukiriguru, should be more able to use the multipliers as an entry point to distribute their new and current modern cultivars quickly and cheaply (Gibson 2013). Distribution of a new cultivar available in only limited quantities could be made even more efficient by choosing multipliers with many customers, ones who marketed over long distances (Mr Maguta) and ones that were widely separated, being located perhaps around different water sources. The last idea would enable neighbouring multipliers to exchange material over the subsequent year(s) to boost supplies still further. Researchers could also get sales data back and so judge adoption of different cultivar. Multipliers could also gain more sales and higher prices from selling modern cultivars.

With farmers commonly travelling up to 20 km to buy vines on-farm, multipliers need to occur every 40km to provide coverage. However, as in Uganda (Rachkara et al. 2015), Mr Maguta easily sold in markets suggesting that multipliers *and* markets selling vines spaced at about every 40 km would also be adequate – a much easier concept to achieve and a major structural improvement to the informal seed system, again achieved by an idea flowing through the formal system, albeit originally derived from the Ugandan informal system. The customers cannot see the original crop, they may pay more but, from the frequency with which vines are sold in markets in Uganda, customers are prepared to accept these disadvantages in exchange for the convenience of being able to buy vines pre-cut and avoid a separate journey to a multiplier. With time, sellers might be able to trade on the quality of their planting material or provide certificates such as Quality Declared Seed (Fajardo et al. 2010). Getting multipliers with ample water supplies (like Mr Maguta) into long distance supply chains to water-constrained areas like Shinyanga and Meatu would also help supply demand where vines are in short supply, with potentially huge benefits to root production and food security. A further structural technology not yet introduced from Uganda is that the jobs of (1) growing the vines, (2) taking them to markets, and (3) selling in market can be done by

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separate people (Rachkara et al. 2015); time will tell whether such job specialisation is useful. Mr Maguta also seemed a 'lead' farmer as several other multipliers from Misungwi and neighbours copied him. He seemed unconcerned that this might create competitors, perhaps thinking that it also may enable the area to be recognised for producing vines and so attract more customers.

Thus overall the results confirm the several opportunities and benefits to be achieved by the formal and the informal systems working together (Almekinders et al. 1994; Thiele 1999) and provide a practical example of the ISSD principle that informal systems can be improved in this way (Louwaars and de Boef 2012). The results confirm for sweetpotato the idea of using the informal seed system to distribute planting material, especially of new cultivars developed by the formal system and support the concept of ISSD (Almekinders et al. 1994; Thiele 1999; Louwaars and de Boef 2012). They also show how the formal system can provide technologies and fresh ideas to revitalize the informal system; these should enable it to provide larger quantities of better quality planting material so that food supplies can then be sustainably increased across the Lake Zone. Despite "Informal seed systems (being) treated as vestigial or marginal to the process of economic development, and (being) more extensively documented by anthropologists, ethnobotanists and geographers" (Nagarajan and Smale 2007), we contend that the informal seed system has much to offer the development of the sweetpotato crop and probably other crops too in Africa. We also agree with McGuire and Sperling (2013) that resilience in seed systems to cope with chronic as well as acute crises derives from the informal private enterprise system. It costs relatively little to work through the informal system; in fact, too much money creates dependency and yet another aid seed system. The main costs are in identifying lead multipliers, from whom ideas, new varieties etc will easily flow into the entire informal system. The formal system is probably more able to absorb resources saved by not giving planting material as direct aid to farmers. We would in particular recommend supporting formal plant breeders, ideally working in a participatory manner, breeding additional top-quality varieties. The informal system is relatively inefficient at this (Gibson et al. 2000), especially at breeding ones with resistance to virus infection, on which informal systems rely (Gibson and Kreuze 2014).

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Captions to figures and plate:

FIGURE 1 A map showing the location of key locations in the Lake Zone of Tanzania together with the main roads and sources of water.

FIGURE 2 A diagram of the production cycle of sweetpotato in the Shinyanga and Meatu regions of Tanzania.

FIGURE 3 Rebeka Mbonje: a female multiplier with <0.25 ha of sweetpotato in the flood plain and hand-carrying water to irrigate.

FIGURE 4 James Kamuga: a male multiplier with 0.5 ha of sweetpotato vines irrigated with a pump

F**IGURE 5** Sebastian Maguta: a medium-sized multiplier with 1 ha of sweetpotato vines irrigated with a pump from a gulf off Lake Victoria

FIGURE 6 A large field of NASPOT 1 in a multiplier’s field in Shinyanga in 2014, just 1 year after disseminating it through a small demonstration trial in his area

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TABLE 1 The different types of multiplier studied and their relative success in maintaining a crop during the 2013 dry season.

Gender (M = male; F = female)	Area (ha) of land planted in the dry season	Type of land ownership	Location (Mis = Misungwi, Shin = Shinyanga, Mea = Meatu	Means of irrigation	Source of water	Success in getting crop through dry season
1M	>0.5	1 owning	1 Mis	Pump	Gulf from Lake Victoria	1M
1M	0.25-0.5	1 owning	1 Shin	Pump	Well a long way from river	1M
9M	0.25-0.5	8 owning + 1 renting	9 Shin	Pump	Well in river flood plain	4M
1M	0.25-0.5	1 owning	1 Shin	Carries water	Well in river bed	1M
1M + 1F	<0.25	2 owning	2 Shin	Water flows to the field	Natural spring	1M + 1F
2M	<0.25	2 renting	2 Shin	Pump	Well a long way from river	0
1M	<0.25	1 owning	1 Shin	Pump	Well in river flood plain	0
1F	<0.25	1 owning	1 Shin	Pump	Well in river bed	1F
1M	<0.25	1 owning	1 Shin	Carries water	Well a long way from river	1M
1M + 3F	<0.25	4 renting	1 Shin + 3 Mea	Carries water	Well in river flood plain	2F
1M + 11F	<0.25	6 owning + 6 renting	9 Shin + 3 Mea	Carries water	Well in river bed	1M + 11F

TABLE 2 Sales by the different types of multipliers in 2013.

Type of multiplier	Number of multipliers	Average number of bundles of vines:				Amount sold per customer	Average revenue (/-) from vines)
		Sold	Own use	Gift*	Total		
With >0.5ha and pumping from Lake Victoria	1	364.5	12.0	5.5	382.0	1.68	1,822,500.0
With 0.25-0.5ha and pumping from a well a long way from river	1	109.5	12.5	3.0	125.0	1.99	547,500.0
With 0.25-0.5ha and pumping from a well in river flood plain	4	115.1	10.3	5.4	130.8	1.81	575,625.0
With 0.25-0.5ha and carrying water from a well in river channel	1	154.0	6.0	6.0	166.0	2.70	770,000.0
With <0.25ha and water flowing from a spring	2	57.3	12.3	7.0	76.5	1.64	286,250.0
With <0.25ha and pumping from a well in river channel	1	75.5	8.0	3.5	87.0	3.97	377,500.0
With <0.25ha and carrying water from a well a long way from river	1	77.0	7.5	5.0	89.5	1.20	385,000.0
With <0.25ha and carrying water from a well in river flood plain	2	54.8	11.0	4.5	70.3	1.66	290,200.0
With <0.25ha and carrying water from a well in river channel	12	59.7	9.2	4.1	73.0	1.58	300,000.0

*Some ‘gifts’ were exchanged for other articles such as a chicken or some future reward.

TABLE 3 The numbers of customers of the different types of multipliers, how far the customers travel and where the sales occur in 2013.

Type of multiplier	Number of multipliers	Average number and type of seed beneficiary				Customers				
						Estimated distances (km) travelled by purchaser to multiplier:				In markets %
		Buyer	Free gift	Own use	Total	0 to 10 %	11 to 20 %	21 to 30 %	31 to 40 %	
With >0.5ha and pumping from Lake Victoria	1	217	8	1	226	13	16	16	8	48
With 0.25-0.5ha and pumping from a well a long way from river	1	55	4	1	60	67	22	7	4	0
With 0.25-0.5ha and pumping from a well in river flood plain	4	64	7	1	72	35	58	7	1	0
With 0.25-0.5ha and carrying water from a well in river channel	1	57	12	1	70	54	33	9	4	0
With <0.25ha and water flowing from a spring	2	35	8	1	44	61	30	6	3	0.0
With <0.25ha and pumping from a well in river channel	1	19	6	1	26	37	47	11	5	0
With <0.25ha and carrying water from a well a long way from river	1	64	10	1	75	75	17	8	0	0
With <0.25ha and carrying water from a well in river flood plain	2	33	3	1	37	44	27	27	2	0
With <0.25ha and carrying water from a well in river channel	12	38	5.5	1	44	36	51	12	1	0

TABLE 4 The effect of different rates of NPK fertilizer on the production of vines and profitability.

a) In 2013

Fertilizer rates (kg/ha)			Cost (/-) of fertilizer/ha*	Harvest of vines/ plot** (3 cuts)	Incremental vine yield/plot	Incremental vine yield/ha	Value (/-) of additional vines/ha***	Incremental cost (/-) of fertilizer/ha	Return on incremental investment
N	P	K							
0	0	0	0	123±21					
50	25	25	340,000	196±21	73	608,176	10,199,119	340,000	x30
150	75	75	1,020,000	288±21	92	765,490	12,837,266	680,000	x19
250	125	125	1,700,000	297±21	9	75,840	1,271,836	680,000	x2

*Cost of 100kg of 20:10:10 NPK fertilizer was 136,000/-

** Values are ± standard error of the mean; plot area harvested was 1.2m2

*** 2,182 bundles of vines, each containing an estimated 300 vines, were sold for 10,975,900/- (Table 2), making a mean value of 1 vine to be 16.8/-

b) In 2014

Fertilizer rates (kg/ha)			Cost (/-) of fertilizer/ha†	Farmyard manure (t/ha) ††	Harvest of vines/ plot** (3 cuts)	Increased vine yield /plot	Increased vine yield/ha	Value (/-) of additional vines/ha***	Return on fertilizer investment
N	P	K							
0	0	0	0	0	140±16.2				
0	0	0	0	10	172±16.2	32	608,176	4,480,000	∞
50	25	25	340,000	5	278±16.2	138	765,490	19,320,000	x57
150	75	75	1,020,000	0	301±16.2	161	75,840	22,540,000	x22

†Prices are maintained at 2013 values for comparability.

††Uncosted because it was difficult to price.

** and *** as above

FIGURE 1 A map showing the location of key locations in the Lake Zone of Tanzania together with the main roads and sources of water.

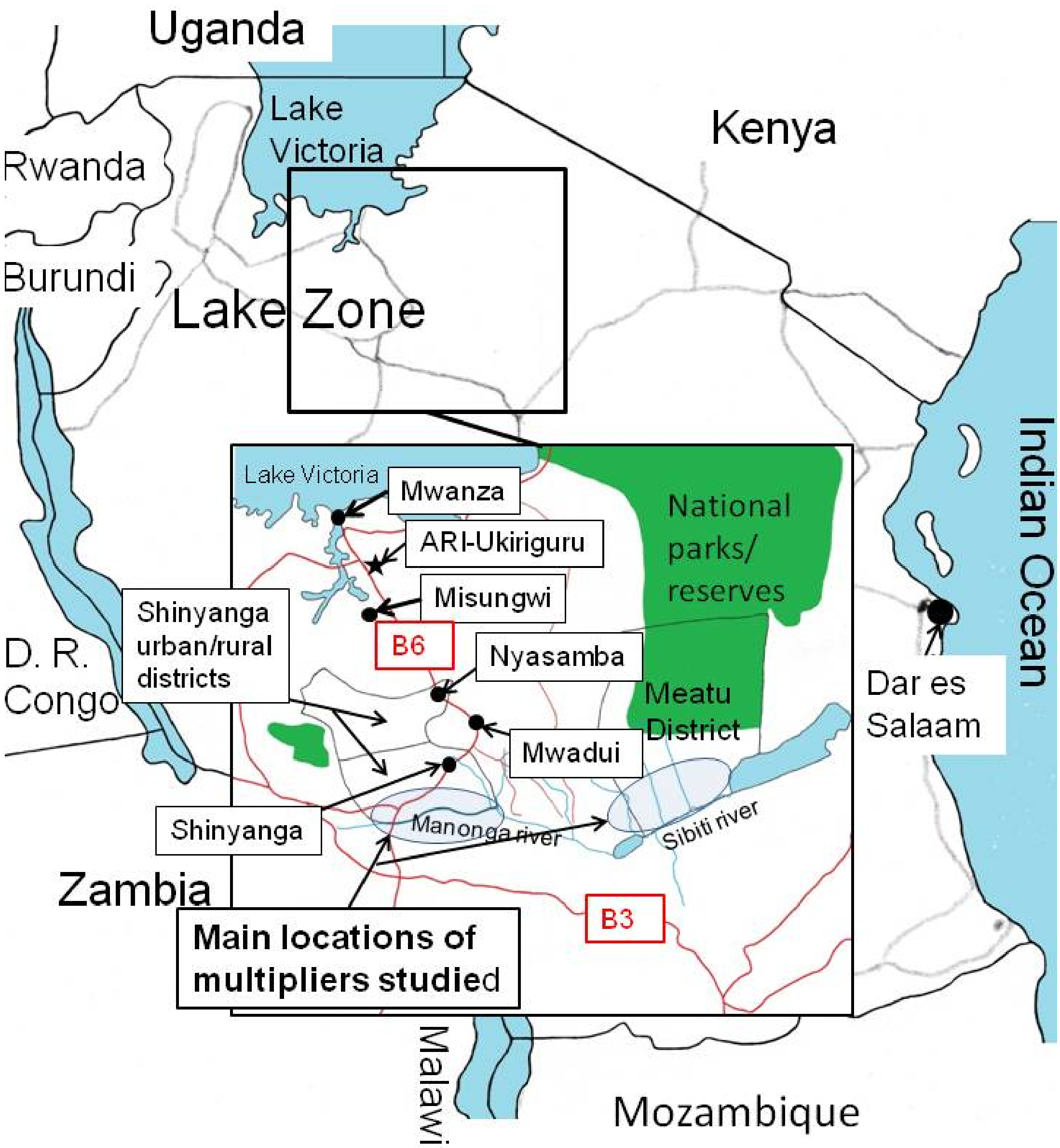

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FIGURE 2 A diagram of the production cycle of sweetpotato in the Shinyanga and Meatu regions of Tanzania.

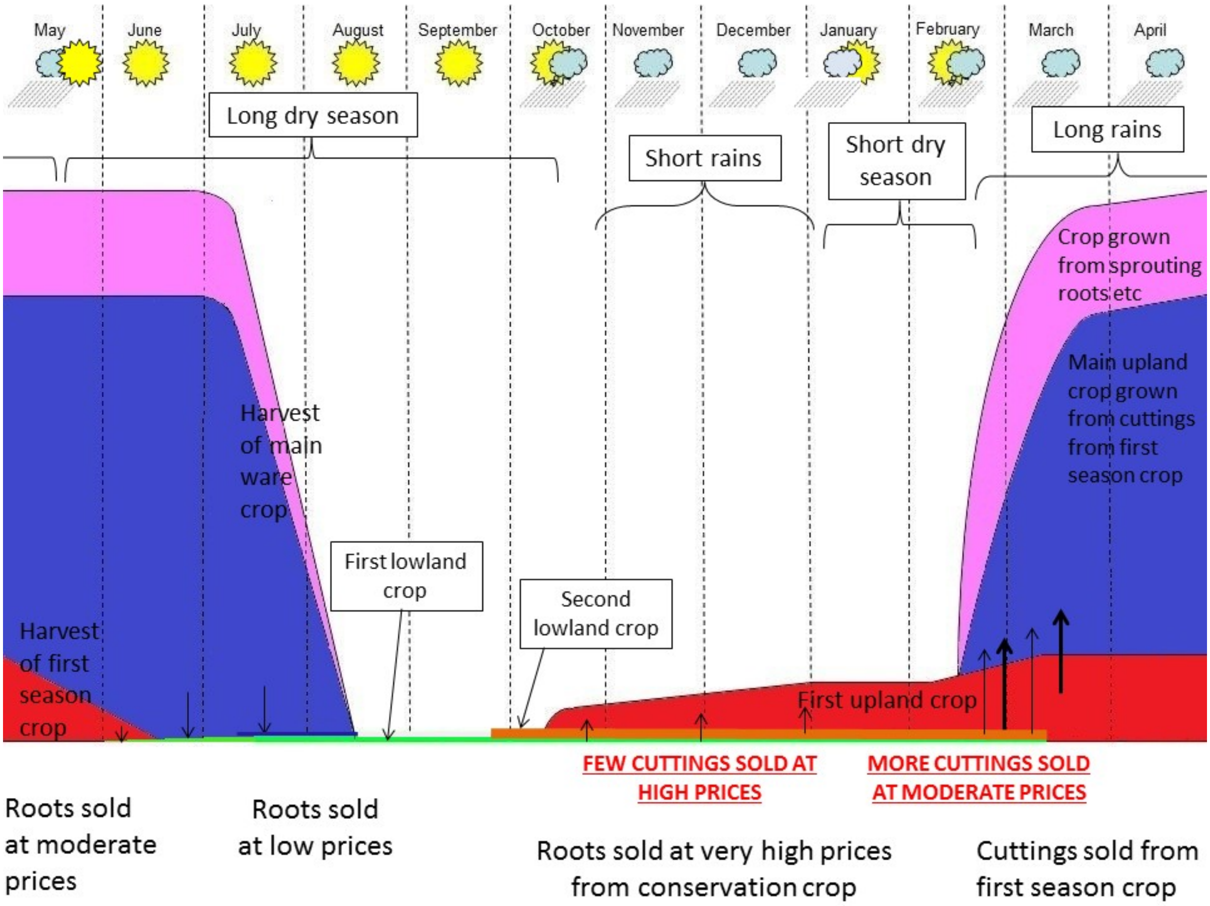

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FIGURE 3 Rebeka Mbonje: a female multiplier with <0.25 ha of sweetpotato in the flood plain and hand-carrying water to irrigate.

Rebeka Mbonje is a vine multiplier in Semu village, Meatu district. Her land is low-lying, has a permanent well on it but she has no pump. She was growing vines of landraces in the traditional way during the dry season for her own use and to sell to customers.

She was supplied with small quantities of modern varieties of OFSP and WFSP and also taught the benefits of fertilizer and RMT in slightly sunken beds to conserve water.

Fertilizer has enabled Rebeka to increase production of vines without using more land or more water, and at little extra cost.

She has increased sales of vines to her local customers, making US$300 this year.

With the extra income, she sends her children to school.

Her three young children also seem healthier from eating β-carotene rich OFSP each morning before school.

FIGURE 4 James Kamuga: a male multiplier with 0.5 ha of sweetpotato vines irrigated with a pump

James Kamuga (right below) grows 0.5ha of vines during the dry season. He is an enterprising multiplier who has dug a deep well to access water for his family and livestock. He also uses it to water his vines and grow other horticultural crops during the dry season. He already has a pump.

James was eager to try out new varieties and technologies. He hosted a demonstration trial for himself and other multipliers. He produced 123 bundles of vines, of which he sold 109.5 bundles to customers who came to buy.

Total returns on tomatoes were greater but selling vines was much easier. Customers harvested the vines themselves while tomatoes had to be harvested, taken to market where they might not sell and the price was uncertain.

Lessons learned by James

1. Sweetpotato vines can be profitable if grown correctly and are easy to manage.
2. James used his income from vines to buy two oxen.

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F**IGURE 5** Sebastian Maguta: a medium-sized multiplier with 1 ha of sweetpotato vines irrigated with a pump from a gulf off Lake Victoria

Sebastian Maguta is a medium scale farmer with land adjoining a gulf from Lake Victoria; he has a petrol pump and grows high-value horticultural crops throughout the year. He is based in Misungwi, near to the B6 tarmac road to Shinyanga and beyond. He sells crops even in Dar es Salaam.

He had been selling bundles of landraces on-farm each year to local farmers. They helped in harvesting and packing so he incurred no marketing costs.

This season, Maguta got modern varieties from ARI Ukiriguru. He also tried selling vines at local markets. This has involved moving vines >100 km on trucks returning empty to Dar es Salaam via Shinyanga and also filling up trucks which he could only half-load with tomatoes. This year, he sold 364.5 bundles, 153 of them to 103 customers in markets at 5,500/- per bundle (500/- more to cover the extra costs).

Mr Maguta and his family had thought that sweetpotato wasn't very profitable. Use of fertilizer and modern varieties has convinced them it is and they are increasing production to >2 ha of vines next year.

Both on-farm and market selling were successes but the latter has more potential for expansion. However, it also has more risks as the vines start to deteriorate once cut to take to market whilst they can wait uncut for local customers to come and buy.

FIGURE 6 A large field of NASPOT 1 in a multiplier’s field in Shinyanga in 2014, just 1 year after disseminating it through a small demonstration trial in his area