Experimental Agriculture (2023), vol. 59, e7, 1–11
doi:10.1017/S0014479723000066

CrossMark

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Ratooning increases production of sweetpotato seed vines multiplied in insect-proof net tunnels in Tanzania

Kwame Ogero[1,2], Haile Selassie Okuku[3], Margaret McEwan[3], Conny Almekinders[4], Jan Kreuze[5], Paul Struik[6] and René van der Vlugt[2]

[1]International Potato Center (CIP), C/o Tanzania Agricultural Research Institute (TARI) – Ukiriguru, P.O. Box 1433, Mwanza, Tanzania, [2]Laboratory of Virology, Plant Sciences, Wageningen University and Research, P.O. Box 16, 6700 AA Wageningen, The Netherlands, [3]International Potato Center, Regional Office for Sub-Saharan Africa (CIP – SSA), ILRI Campus, Old Naivasha Road, P.O. Box 25171-00603, Nairobi, Kenya, [4]Knowledge, Technology and Innovation Group, Social Sciences, Wageningen University and Research, P.O. Box 8130, 6700 EW Wageningen, The Netherlands, [5]International Potato Center, Avenida La Molina 1895, Apartado 1558, Lima 12, Perú, USA and [6]Centre for Crop Systems Analysis, Plant Sciences, Wageningen University and Research, P.O. Box 430, 6700 AK Wageningen, The Netherlands

Corresponding author: Paul Struik; email: paul.struik@wur.nl

(Received 31 December 2022; revised 22 March 2023; accepted 15 April 2023)

Summary

Insect-proof net tunnels can help reduce virus infection of clean virus-tested sweetpotato seed produced by decentralized seed producers. However, optimal management is required to maintain both quality and quantity of seed produced. This study investigated the effect of the ratoon cropping technique on vine production in net tunnels and open fields. Virus-tested planting material of two varieties, Kabode and Mataya, were grown in net tunnels and open fields. Each variety had 80 plants per plot, with 40 following the ratooning technique and 40 a replanting technique. The ratooned crop was harvested six times, comprising the initial harvest and five regrowths. This covered 14 months representing six generations of vine production. The number of vines, number of nodes per vine, and vine length were recorded. The number of plants showing virus symptoms was also recorded. The ratoon cropping technique produced more vines compared with the replanting technique in both net tunnels and open fields. Cv. Kabode produced more vines in open fields compared with net tunnels regardless of cropping technique. On the other hand, cv. Mataya produced relatively equal numbers of vines in net tunnels and open fields. Despite ratooning leading to more vine production compared with replanting, the technique led to higher virus incidences on plants grown in the open. This also varied with variety with the highest virus disease incidences being recorded on cv. Mataya. We recommend the ratoon cropping technique for sweetpotato vine production in net tunnels. Replanting technique should be adopted for vine production in the open fields because it acts as a key control strategy for virus infections even for susceptible varieties.

Keywords: Cropping technique; *Ipomoea batatas*; Regrowth; Replanting

Introduction

Farmers in Tanzania are yet to realize the full potential of the sweetpotato (*Ipomoea batatas*) crop. The main yield constraint is virus infection of propagation material. Virus spread is aided by vegetative propagation of planting material, that is, seed vine recycling from season to season and by farmer-to-farmer exchange of planting material. More than 90% of sweetpotato seed vines is sourced from an informal farmer-based seed system characterized by free exchange of local landraces (McEwan, 2016; Namanda *et al.*, 2011; Thiele *et al.*, 2021). Very little clean virus-tested seed and very few improved varieties are disseminated through this system. The farmer-based system is made possible by the vegetative nature of the crop which makes it easier for farmers to propagate their own planting material.

This challenge to control virus diseases is not unique to sweetpotato and affects the seed systems of other vegetatively propagated crops such as banana, cassava, and potato. Vegetative propagation in root, tuber, and banana crops allows farmers to reproduce the same genetic material for many seasons but can lead to degeneration of the crop, whereby yields decline from season to season due to accumulation of pathogens in the plant (Almekinders *et al.*, 2019; Thomas-Sharma *et al.*, 2016).

In sweetpotato, synergistic reactions resulting from co-infection with sweetpotato feathery mottle virus (SPFMV; *Potyvirus*, transmitted by aphids) and sweetpotato chlorotic stunt virus (SPCSV; *Crinivirus*, transmitted by whiteflies) have been particularly identified as a key yield-limiting factor (Clark *et al.*, 2012). Infection with the two viruses causes a disease complex known as sweetpotato virus disease (SPVD) which leads to 56–100% yield losses (Adikini *et al.*, 2016; Mukasa *et al.*, 2003). Therefore, the focus of seed system interventions has been to disseminate and promote the use of clean, virus-tested seed vines (further referred to as seed) of market-preferred landraces and improved varieties.

Use of cleaned-up, virus-tested sweetpotato seed is recognized as one of the strategies to address virus-related yield losses in sweetpotato in sub-Saharan Africa (SSA) (McEwan, 2016). This approach has been reported to be successful with immense economic benefits across the world. Clark *et al.* (2010) reported that farmers in the USA realized better yields by incorporating virus-tested foundation seed into their production schemes. In China, use of virus-free seed in Shandong province led to an internal rate of return of 202% due to increased yields (Fuglie *et al.*, 1999). However, virus-free sweetpotato seed can get infected once it is grown in farmers' fields. The rate of infection may vary depending on management, proximity to other sweetpotato fields or alternate virus hosts, virus vector densities, and weather conditions. Often, dissemination of virus-free sweetpotato seed in Eastern Africa is accompanied with farmer training on on-farm seed management strategies to delay or reduce the rate of infection. Most target farmers want to become specialized seed producers. In addition to human capacity building, the specialized seed producers are also capacitated to acquire technologies that can help protect clean planting material from virus vectors. This includes the use of low-cost insect-proof net tunnels which have been shown to reduce virus infection in SSA countries including Tanzania (Ogero *et al.*, 2019).

Whereas use of insect-protected structures is common at research institutions in SSA, they are rarely used at farmer level, because the production of sweetpotato seed at farmer level has never been technology-intensive. However, as more areas become high-virus-pressure zones due to increasing vector populations (Trebicki, 2020), it is important for seed producers to adopt technologies that will lower the rates of infection of cleaned-up virus-tested sweetpotato seed. Use of low-cost insect-proof net tunnels to multiply cleaned-up virus-tested sweetpotato seed at seed producer level has been piloted in seven countries in SSA (Ogero *et al.*, 2017). This pilot showed that the technology can be successfully used by better resourced, trained farmers, to maintain and produce high-quality basic seed for 2 to 3 years. However, for successful uptake, seed producers also need to adopt appropriate management practices to maintain the quality and quantity of planting material in the net tunnels.

Keeping the plants in a healthy status enables several harvests, that is, the plants can be let to sprout again after harvesting. In sweetpotato, the first harvest of vines can be done 90 days after planting and thereafter harvesting can be done after every 40–60 days. This is called ratooning, and it consists of harvesting the crop, with the next crop being the result of the first crop's regrowth (Riga, 2008). However, this technique can affect the quality and quantity of planting material produced, because the root stocks age with time. We assessed how ratooning affects vine production for two sweetpotato varieties multiplied in net tunnels over 14 months. This was

https://doi.org/10.1017/S0014479723000066 Published online by Cambridge University Press

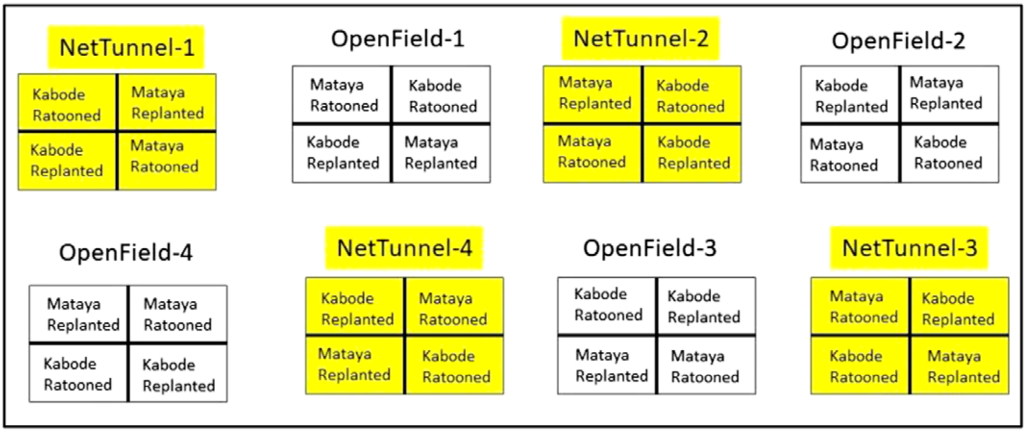

Figure 1. Schematic diagram showing the field layout.

compared with another cropping technique that entailed uprooting old plants at harvest and replanting with apical portions of the same crop. Here, the plants are cut at about 10–15 cm aboveground, root stocks uprooted, and the bed prepared afresh. The harvested vines are then cut into three-node (10-cm) cuttings and replanted.

Materials and Methods

Location and varieties

The experiment was conducted at a satellite research farm operated by the Tanzania Agricultural Research Institute (TARI) – Ukiriguru at Nyakasanga village, Misungwi district, Mwanza, Tanzania, located at 2° 46' 14" S, 32° 56' 34" E, at an altitude of 1139 m asl. The site was about 300 m from the shore of Lake Victoria from where irrigation water was drawn. The location has two rain seasons in a year (March–mid-May and October–December). Two varieties, Kabode and Mataya, were used in the experiment. Both varieties are orange-fleshed but have different growth characteristics. Kabode has a semi-erect canopy and is moderately resistant to sweetpotato viruses, while Mataya is prostrate and susceptible to viruses.

Experimental set up

The trial was set up in a split-split plot design with the following factors:

(a) Cover type (net tunnel vs. open field) – main plot factor
(b) Variety (cv. Kabode vs. cv. Mataya) – subplot factor
(c) Cropping technique (ratooning vs. replanting) – sub-sub plot factor

This led to eight treatments each replicated within each of the four main plots, four open-field plots, and four net tunnel-protected plots measuring 3 m × 1.7 m (Figure 1).

HOBO® Pro v2 Temperature/Relative Humidity data logger by Onset Computer Corporation (470 MacArthur Blvd, Bourne, MA 02532) was used to measure relative humidity and temperature in the net tunnels and open-field plots.

https://doi.org/10.1017/S0014479723000066 Published online by Cambridge University Press

Planting and crop management

At the beginning of the experiment, each treatment was planted with 40 three-node, clean, virus-tested cuttings sourced from TARI – Ukiriguru. The plant spacing for each treatment both in net tunnels and open fields was 20 cm × 10 cm, that is, 20 cm between rows and 10 cm between plants. The first harvest was done 85 days after planting. Subsequent harvests were done after every 60 days. Vines of plants under the ratooning cropping technique were harvested at about 10–15 cm above the ground and left to sprout again. Therefore, the next crop was the result of the previous crop regrowth. This was repeated for the subsequent harvests. On the other hand, plants following the replanting cropping technique were uprooted during each harvest, and three-node vine cuttings obtained from the apical portions were replanted. The experiment was run for 14 months (September 21, 2019–November 17, 2020) representing six generations of vine production. A mulch of rice husks was applied at establishment and after every harvest to suppress weeds. In addition, any weed that may have established during the growing period was uprooted during harvesting. During the dry season, irrigation was done three times per week. Three buckets of composite manure were applied per main plot during establishment. After every harvest, NPK (17:17:17) was applied at 200 g per main plot.

Data collection and analysis

The total number of vines produced per treatment was recorded at each harvest. At the same time, five vines were randomly selected from each treatment to determine the average number of nodes and vine length. Three-way analysis of variance (ANOVA) for split-split plot design was used to determine whether there were any statistically significant effects of the three factors: cover type, variety, and cropping technique or their two-way or three-way interactions on the continuous dependent variables of number of vines, number of nodes, and vine length. The analysis comprised of the second to the sixth generations representing the first to the fifth ratooning and replanting. Generation one was left out because it represented experimental establishment, that is, initial planting of the crops that would be ratooned and those to be replanted and therefore no differences in treatments.

In recording virus disease incidence, the number of plants with visual virus symptoms was counted during harvest and virus disease incidence per treatment plot was calculated as follows:

$$Virus\ disease\ incidence\ (\%) = \frac{Number\ of\ infected\ plants}{Total\ number\ of\ plants\ per\ treatment\ i.e.\ 40} x100$$

The visual symptoms were mostly those relating to SPVD, SPCSV, and SPFMV including severe stunting, leaf chlorosis, fan-shaped leaves, interveinal chlorosis, interveinal purpling, and purple rings (Clark *et al.*, 2013).

Results

Temperature and relative humidity

The average temperature and relative humidity in net tunnels and open fields were similar. However, the highest temperature and relative humidity were recorded in the net tunnels (Table 1).

Number of vines per plot

There was a significant interaction between variety and cropping technique ($p = 0.04$), with larger differences between techniques for cv. Mataya than for cv. Kabode. The ratoon cropping technique produced more vines than the replanting technique ($p < 0.001$), irrespective of cover type

https://doi.org/10.1017/S0014479723000066 Published online by Cambridge University Press

Table 1. Temperature and relative humidity in net tunnels and open fields

	Temperature, °C			Relative humidity, %		
	Average	Highest	Lowest	Average	Highest	Lowest
Net tunnels	23.8	32.0	19.1	80.4	100.0	51.9
Open fields	23.5	29.2	19.5	82.2	99.3	58.4

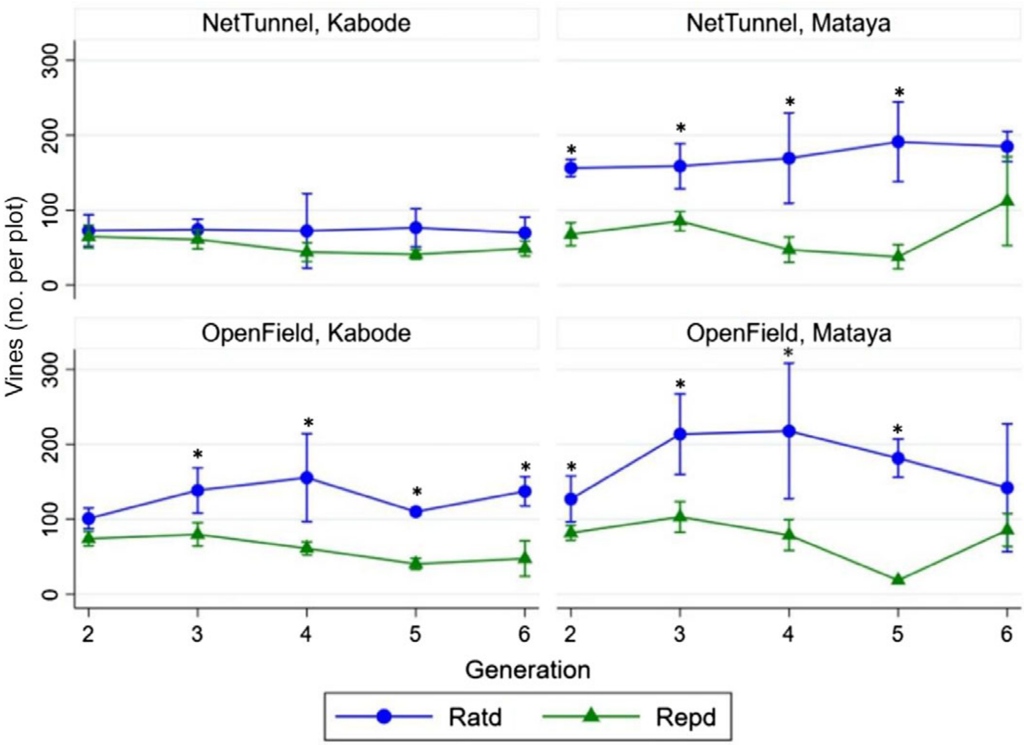

Figure 2. Trend in number of vines produced in net tunnels and open fields under ratoon cropping technique (Ratd) and replanting technique (Repd).

(open field vs. net tunnel), as well as across the two varieties (Figure 2). For cv. Kabode, the two cropping techniques did much better in open fields than in net tunnels. Open fields for ratooned crop consistently produced more vines than replanted crops across the generations ($p < 0.001$) and were significantly different at each generation. Cv. Mataya produced many more vines than cv. Kabode in both the net tunnels and in the open fields. In addition, the variety's ratooned plants produced significantly more vines than replanted plants in all but the sixth generation. This was observed both in net tunnels and open fields.

Vine length

Ratooned and replanted plants of both varieties planted in net tunnels produced longer vines than those planted in open fields ($p < 0.0001$; Figure 3). For cv. Kabode, ratooned plants in open fields had longer vines compared to those replanted in the third and fifth generations ($p = 0.0006$). In net tunnels, the ratooned plants produced longer vines than replanted plants in the fifth generation ($p = 0.004$). Plants of cv. Mataya grown in net tunnels under the ratoon cropping technique

https://doi.org/10.1017/S0014479723000066 Published online by Cambridge University Press

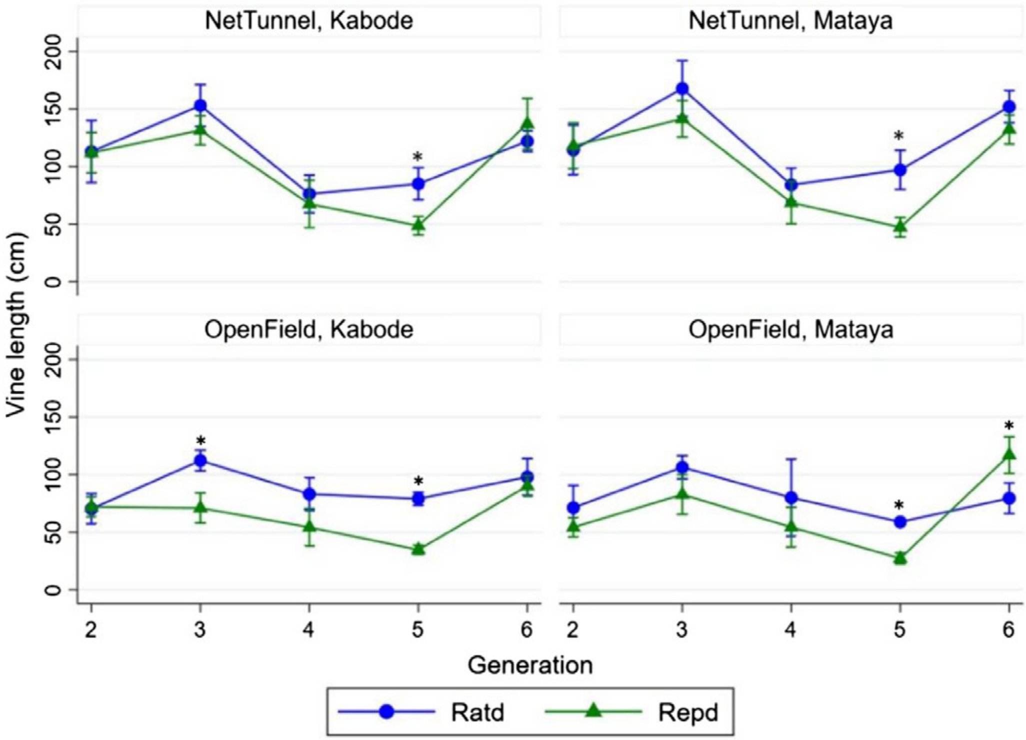

Figure 3. Trend in average vine length in net tunnels and open fields under ratoon cropping technique (Ratd) and replanting technique (Repd).

produced longer vines than replanted plants in the fifth generation ($p = 0.002$). In the open fields, the variety also produced longer vines under ratooning than after replanting in the fifth generation ($p < 0.0001$). Plants of cv. Mataya replanted in open fields in the sixth generation produced significantly longer vines than ratooned plants.

Number of nodes per vine

Vines from ratooned plants of cvs. Kabode and Mataya produced more nodes compared to replanted plants from the second to the fifth generation (Figure 4). This was observed both in net tunnels and open fields. However, the difference between cultivars was not significant in all generations and cover types. For cv. Kabode, the difference between cropping techniques was significant only in open fields during the third and fifth generations. In the last generation, replanted plants of cv. Kabode grown in net tunnels produced more nodes per vine than the ratooned plants. For cv. Mataya, ratooned crops produced significantly more nodes per vine than replanted crops both in net tunnels and open fields in the fifth generation.

Incidence of virus disease

Ratooned and replanted plants grown in net tunnels had no virus symptoms during the entire experiment. Replanted plants grown in open fields also had no virus symptoms in all the generations. On the other hand, ratooned plants grown in open fields started showing virus symptoms in the fourth generation (Figure 5). The symptoms increased in the fifth and sixth generations with cv. Mataya being more affected than cv. Kabode.

https://doi.org/10.1017/S0014479723000066 Published online by Cambridge University Press

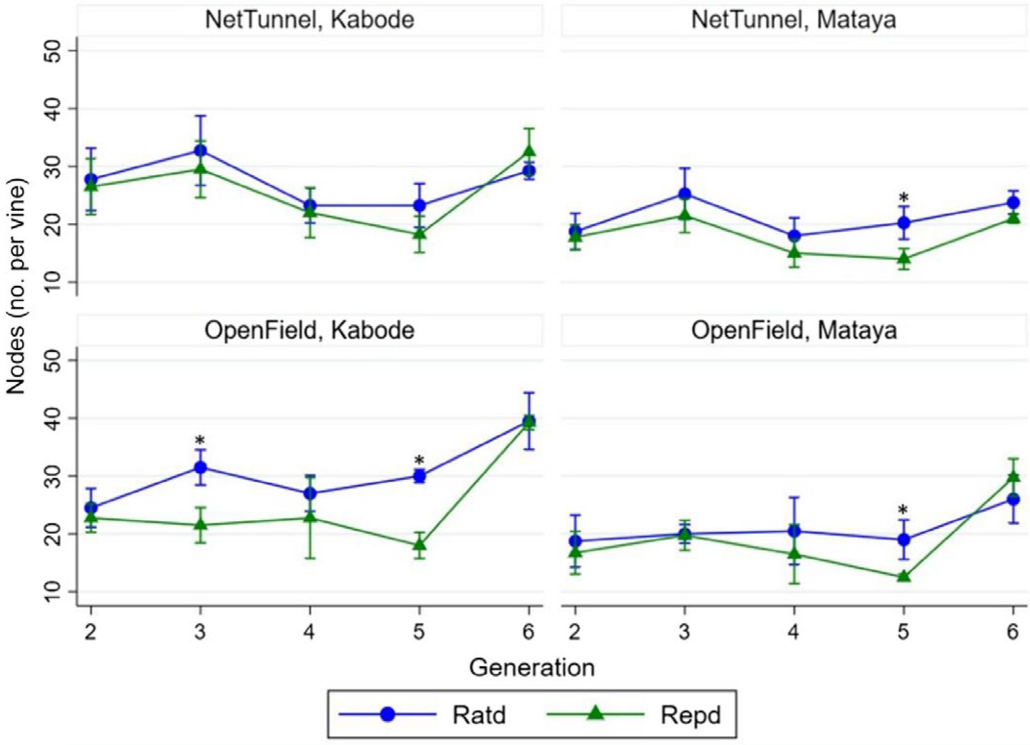

Figure 4. Trend in number of nodes per vine produced in net tunnels and open fields under ratoon cropping technique (Ratd) and replanting technique (Repd).

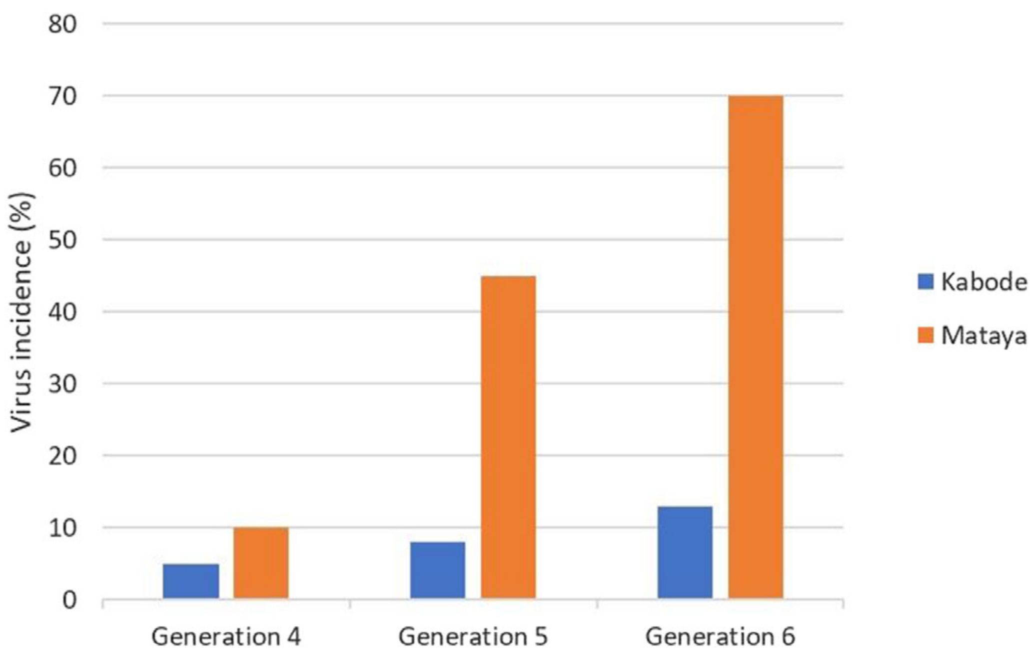

Figure 5. Percentage virus incidences on ratooned plants grown in open fields for cv. Kabode and cv. Mataya.

https://doi.org/10.1017/S0014479723000066 Published online by Cambridge University Press

Discussion

Effect of ratooning on vine production

The ratoon cropping technique, also known as the 'reaping and regrowth system of production', has been reported to increase yields in plants that can regenerate leaves and/or shoots after harvesting leaves or shoots and is maximized in vegetable production (Fu, 2008; Riga, 2008). Sweetpotato behaves similarly producing new shoots from vines that have been harvested about 10 cm above ground, thereby enabling seed producers to maximize seed production from a single planting. In this study, it was demonstrated that ratooning maintains vine production in net tunnels better than replanting after each harvest. This may be explained by more frequent branching in ratooned crops by removing apical dominance (Wang *et al.*, 2020). In addition, old stems and roots tend to have more carbohydrate reserves that give the ratooned crop a head start compared to the replanted crop (de Booysen and Nelson, 1975). This has been observed in other crops as well. For instance, sugarcane plants with the entire root system intact have been reported to produce photoassimilates earlier, expediting regrowth and leading to more accumulation of biomass than in plants with 50% of the root system (Pissolato *et al.*, 2021). The replanted crop requires more time to develop roots and leaves to photosynthesize. The newly planted crop does not use light and thermal sources efficiently at this stage of root development (Xu *et al.*, 2021).

The recommended harvest time of seed vines from newly planted sweetpotato vine cuttings is 90 days, whereas a ratooned crop can be harvested after 40–60 days (Stathers *et al.*, 2018). This means that the replanted crop needs more time to fully develop. This may also explain why the ratooned plants had longer vine length than the replanted plants.

The superior effect of the ratoon cropping technique was also noted in the number of nodes produced. The number of vines and the number of nodes per vine are important parameters in sweetpotato seed production in SSA. Therefore, by producing more vines and more nodes per vine, ratooning increases the number of seed cuttings produced. Each node has a meristem, and seed is usually multiplied by planting three-node cuttings, with two nodes being buried in the soil to produce roots while one node remains above ground to produce a shoot. The more the nodes per vine, the higher the number of seed cuttings that can be realized.

Effect of genotype on vine production

Ratooned and replanted vine production in net tunnels and open fields was influenced by variety. Cv. Kabode produced more vines in open fields than in net tunnels regardless of the cropping technique. On the other hand, cv. Mataya produced a similar number of vines in net tunnels and open fields for both ratooned and replanted crops. Genotypic variation influences sweetpotato vine production, and this has also been reported in plants produced in screen houses using a sandponics system (Makokha *et al.*, 2020). The morphology of cv. Kabode might have contributed to the production of more vines in open fields than in net tunnels. The variety is semi-erect and tends to grow upward when grown in areas with limited space as was the case in the net tunnels. The structure of the net tunnel meant that plants grown therein had to be fully accommodated within the 3 m $\times$ 1.7 m bed due to restriction by the net, whereas those grown in the open field could spread outside the bed area. Open fields provided enough space for the variety to spread and branch. This might have increased the number of leaves, thereby increasing the leaf area. By spreading, the plant increases the area exposed to light, thereby increasing plant photosynthesis. Plant type plays a key role in the interception and utilization of solar energy which is important in increasing canopy photosynthesis (Brodersen and Vogelmann, 2010; Feng *et al.*, 2016). Yin and Struik (2017) reported that the daily canopy photosynthesis increases with increasing leaf area index because of a higher interception of photosynthetically active radiation.

Ratooning and virus disease incidence

The ratoon cropping technique produced more vines in both the net tunnels and in the open fields, but it also added to a progressive increase in virus disease incidence on plants grown in the open. Ratooning has been reported to increase disease incidences and build-up of pests (Plucknett *et al.*, 1970). Previous studies have demonstrated this in rice (Santos *et al.*, 2003) and sugarcane (Young, 2018). Sweetpotato viruses are systemic infecting all parts of the plant, and ratooning may lead to a gradual increase in overall virus titers in plants. Previous reports indicated persistence of viruses in sweetpotato plants over several cropping cycles (Gibson and Kreuze, 2015). The plants grown in net tunnels did not show any virus symptoms, supporting previous findings by Ogero *et al.* (2019) that the insect-proof nets protect clean seed from infection. Open-field production exposes clean seed to virus vectors that can transmit diseases from nearby fields. The extent of infection and symptom expression is influenced by virus tolerance levels of a particular cultivar as shown by differences in virus disease incidences between cv. Kabode and cv. Mataya in this study. The virus disease incidences in this study were based on visual symptoms. Testing of plant samples using a sensitive molecular-based diagnostic method could have given a better understanding of the incidences even for symptomless plants. It is also important to study the time it takes for a plant to show virus symptoms after infection.

Conclusions

This long-term experiment has shown that ratooning has an advantage for sweetpotato vine production, not only in net tunnels but also in open fields. The technique can make management of vines grown in net tunnels easier. The net tunnels are small measuring 3.0 m × 1.7 m × 1.4 m which makes it tedious for an adult to enter for regular management. Replanting means spending more time inside which can discourage someone from adopting the technology. With the ratoon cropping technique, the vine production cycle is reduced from about 90 days (as is for newly planted cuttings) to 40–60 days, thereby reducing labor costs per cycle. In addition, the ratoon cropping technique reduces costs of production, because replanting is not required after every harvest. Based on these findings, we recommend the technique for sweetpotato vine production in the net tunnels. The technique can contribute toward easier adoption of insect-proof net tunnels to protect clean sweetpotato seed from virus infection. Replanting technique should be adopted in open-field production, because this research has shown that it is a good control strategy for viruses even for susceptible varieties. This is the first detailed study investigating the effect of ratooning in sweetpotato seed production. The study focused mostly on parameters associated with the number of seed vines produced, that is, number of vines, number of nodes per vine, and vine length, and touched only partly on virus infection in open fields. Further studies are needed to investigate the effect of various environmental and management factors on regrowth of ratooned vines. These may include effect of temperature, water stress, and carbohydrate reserve in root stocks.

Financial support. This research was undertaken as part of, and funded by, the CGIAR Research Program on Roots, Tubers and Bananas (RTB) and was supported by CGIAR Fund Donors, including the NWO (www.nwo.nl). Funding support for this work was provided by Bill and Melinda Gates Foundation through grants to SASHA (ID: OPP1019987) and SweetGAINS (ID: OPP121332).

Competing Interest. The author(s) declare none.

References

Adikini S., Mukasa S.B., Mwanga R.O.M. and Gibson R.W. (2016). Effects of sweet potato feathery mottle virus and sweet potato chlorotic stunt virus on the yield of sweetpotato in Uganda. *Journal of Phytopathology* **164**, 242–254. https://doi.org/10.1111/jph.12451

Almekinders C.J.M., Walsh S., Jacobsen K.S., Andrade-Piedra J.L., McEwan M.A., de Haan S., Kumar L. and Staver C. (2019). Why interventions in the seed systems of roots, tubers and bananas crops do not reach their full potential. *Food Security* **11**, 23–42. https://doi.org/10.1007/s12571-018-0874-4

Brodersen C.R. and Vogelmann T.C. (2010). Do changes in light direction affect absorption profiles in leaves? *Functional Plant Biology* **37**, 403–412. https://doi.org/10.1071/FP09262

Clark C.A., Davis J.A., Abad J.A., Cuellar W.J., Fuentes S., Kreuze J.F., Gibson R.W., Mukasa S.B., Tugume A.K., Tairo F.D. and Valkonen J.P.T. (2012). Sweetpotato viruses: 15 years of progress on understanding and managing complex diseases. *Plant Disease* **96**, 168–185. https://doi.org/10.1094/PDIS-07-11-0550

Clark C.A., Ferrin D.M., Smith T.P. and Holmes G.J. (2013). *Compendium of Sweetpotato Diseases, Pests, and Disorders*, 2nd Edn: The American Phytopathological Society. https://doi.org/10.1094/9780890544952.

Clark C.A., Smith T.P., Ferrin D.M. and Villordon A.Q. (2010). Performance of sweetpotato foundation seed after incorporation into commercial operations in Louisiana. *HortTechnology* **20**, 977–982. https://doi.org/10.21273/Hortsci.20.6.977

de Booysen P.V. and Nelson C.J. (1975). Leaf area and carbohydrate reserves in regrowth of Tall Fescue1. *Crop Science* **15**, 262–266. https://doi.org/10.2135/cropsci1975.0011183X001500020036x

Feng G., Luo H., Zhang Y., Gou L., Yao Y., Lin Y. and Zhang W. (2016). Relationship between plant canopy characteristics and photosynthetic productivity in diverse cultivars of cotton (*Gossypium hirsutum* L.). *The Crop Journal* **4**, 499–508. https://doi.org/10.1016/j.cj.2016.05.012

Fu J. (2008). Effects of different harvest start times on leafy vegetables (Lettuce, Pak Choi and Rocket) in a reaping and regrowth system. PhD Thesis: Lincoln University, Pennsylvania, USA.

Fuglie K., Zhang L., Salazar L. and Walker T. (1999). *Economic Impact of Virus-Free Sweetpotato Planting Material in Shandong Province, China*. Lima, Peru: International Potato Center, No. 1997–98; pp. 249–254.

Gibson R.W. and Kreuze J.F. (2015). Degeneration in sweetpotato due to viruses, virus-cleaned planting material and reversion: a review. *Plant Pathology* **64**, 1–15. https://doi.org/10.1111/ppa.12273

Makokha P., Ssali R.T., Rajendran S., Wanjala B.W., Matasyoh L.G., Kiplagat O.K., McEwan M.A. and Low J.W. (2020). Comparative analysis for producing sweetpotato pre-basic seed using sandponics and conventional systems. *Journal of Crop Improvement* **34**, 84–102.

McEwan M. (2016). *Sweetpotato Seed Systems in Sub-Saharan Africa: A Literature Review to Contribute to the Preparation of Conceptual Frameworks to Guide Practical Interventions for Root, Tuber, and Banana Seed Systems*. CGIAR Research Program on Roots, Tubers and Bananas (RTB). Lima, Peru: International Potato Center.

Mukasa S.B., Rubaihayo P.R. and Valkonen J.P.T. (2003). Incidence of viruses and virus like diseases of sweetpotato in Uganda. *Plant Disease* **87**, 329–335. https://doi.org/10.1094/PDIS.2003.87.4.329

Namanda S., Gibson R. and Sindi K. (2011). Sweetpotato seed systems in Uganda, Tanzania, and Rwanda. *Journal of Sustainable Agriculture* **35**, 870–884. https://doi.org/10.1080/10440046.2011.590572

Ogero K., Njoku J. and McEwan M. (2017). *Protecting Sweetpotato Planting Material from Viruses Using Insect Proof Net Tunnels: A Guide to Construct and Use Net Tunnels for Quality Seed Production*, 2nd Edn. Lima, Peru: International Potato Center.

Ogero K.O., Kreuze J.F., McEwan M.A., Luambano N.D., Bachwenkizi H., Garrett K.A., Andersen K.F., Thomas-Sharma S. and van der Vlugt R.A.A. (2019). Efficiency of insect-proof net tunnels in reducing virus-related seed degeneration in sweetpotato. *Plant Pathology* **68**, 1472–1480. https://doi.org/10.1111/ppa.13069

Pissolato M.D., da Cruz L.P., Silveira N.M., Machado E.C. and Ribeiro R.V. (2021). Sugarcane regrowth is dependent on root system size: an approach using young plants grown in nutrient solution. *Bragantia* [online] **80**, e4321. https://doi.org/10.1590/1678-4499.20210039 [Accessed 16 June 2022], Available from: Epub 13 Aug 2021. ISSN: 1678-4499.

Plucknett D.L., Evenson J.P. and Sanford W.G. (1970). Ratoon cropping 11. Hawaii Agricultural Experiment Station, Journal Series No. 1168. In Brady N.C. (ed.), *Advances in Agronomy*: Academic Press, **22**, pp. 285–330. https://doi.org/10.1016/S0065-2113(08)60271-0

Riga P. (2008). Ratoon cropping technique combined with pluriannual character improves soilless pepper (*Capsicum annuum* L.) fruit yield. *Spanish Journal of Agricultural Research* **6**, 430–433. https://doi.org/10.5424/sjar/2008063-343.

Santos A.B., Fageria N.K. and Prabhu A.S. (2003). Rice ratooning management practices for higher yields. *Communications in Soil Science and Plant Analysis* **34**, 881–918. https://doi.org/10.1081/CSS-120018981

Stathers T., McEwan M., Gibson R., Mwanga R., Carey T., Namanda S., Low J., Ogero K., Rajendran S., Agili S., Abidin E., Malinga J., Andrade M. and Mkumbira J. (2018). Topic 5: sweetpotato seed systems. In: Stathers S. (ed), *Everything You Ever Wanted to Know about Sweetpotato: Reaching Agents of Change ToT Manual*. Lima, Peru: International Potato Center, p. 118.

Thiele G., Dufour D., Vernier P., Mwanga R.O.M., Parker M.L., Schulte Geldermann E., Teeken B., Wossen T., Gotor E., Kikulwe E., Tufan H., Sinelle S., Kouakou A.M., Friedmann M., Polar V. and Hershey C. (2021). A review of varietal change in roots, tubers and bananas: consumer preferences and other drivers of adoption and implications for breeding. *International Journal of Food Science & Technology* **56**, 1076–1092. https://doi.org/10.1111/ijfs.14684

Thomas-Sharma S., Abdurahman A., Ali S., Andrade-Piedra J.L., Bao S., Charkowski A.O., Crook D., Kadian M., Kromann P., Struik P.C., Torrance L., Garrett K.A. and Forbes G.A. (2016). Seed degeneration in potato: the need for an integrated seed health strategy to mitigate the problem in developing countries. *Plant Pathology*, **65**, 3–16. https://doi.org/10.1111/ppa.12439

Trebicki P. (2020). Climate change and plant virus epidemiology. *Virus Research*, **286**, 198059. https://doi.org/10.1016/j.virusres.2020.198059

Wang W., He A., Jiang G., Sun H., Jiang M., Man J., Ling X., Cui K., Huang J., Peng S. and Nie L. (2020). Chapter four—ratoon rice technology: a green and resource-efficient way for rice production. In Sparks D.L. (ed.), *Advances in Agronomy*: Academic Press, **159**, pp. 135–167. https://doi.org/10.1016/bs.agron.2019.07.006

Xu F., Wang Z., Lu G., Zeng R. and Que Y. (2021). Sugarcane ratooning ability: research status, shortcomings, and prospects. *Biology* **10**, 1052. PubMed. https://doi.org/10.3390/biology10101052

Yin X. and Struik P.C. (2017). Can increased leaf photosynthesis be converted into higher crop mass production? A simulation study for rice using the crop model GECROS. *Journal of Experimental Botany* **68**, 2345–2360. https://doi.org/10.1093/jxb/erx085

Young A.J. (2018). Turning a blind eye to ratoon stunting disease of sugarcane in Australia. *Plant Disease* **102**, 473–482. https://doi.org/10.1094/PDIS-06-17-0911-FE

Cite this article: Ogero K, Okuku HS, McEwan M, Almekinders C, Kreuze J, Struik P, and van der Vlugt R. Ratooning increases production of sweetpotato seed vines multiplied in insect-proof net tunnels in Tanzania. *Experimental Agriculture*. https://doi.org/10.1017/S0014479723000066