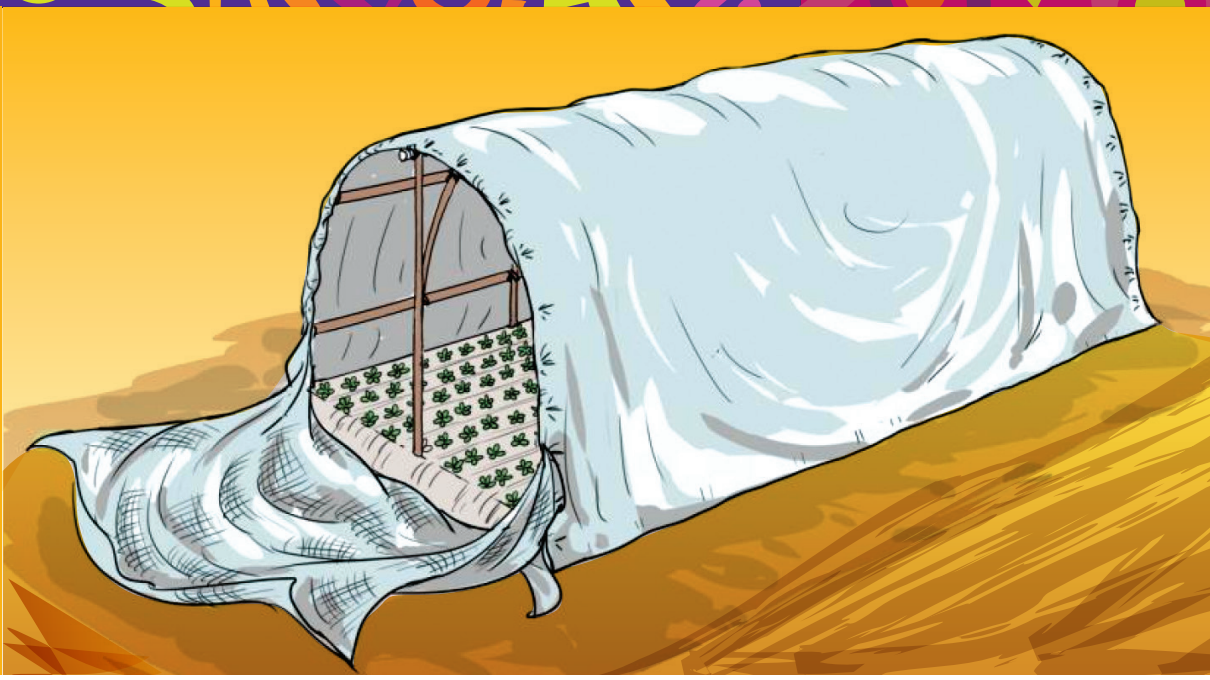

Protecting Sweetpotato Planting Material from Viruses using Insect Proof Net Tunnels

A Guide to Construct and Use Net Tunnels for Quality Seed Production

July 2017
Second Edition

CIP INTERNATIONAL POTATO CENTER
A CGIAR RESEARCH CENTER

SASHA
Sweetpotato Action for Security and Health in Africa

KALRO
Kenya Agricultural & Livestock Research Organization

CGIAR
RESEARCH PROGRAM ON
Roots, Tubers and Bananas

Introduction

One of the major yield-limiting factors in sweetpotato production is the lack of clean planting material owing to infection by sweet potato virus disease (SPVD). Viruses are spread by insect vectors such as white flies and aphids and they build up over time in the plants, reducing yields with each season. Some sweetpotato varieties are more resistant to virus infection than others, showing less yield loss, and breeding programs in Africa focus on selecting for this very important trait. So-called susceptible varieties can disappear completely in one or two seasons in areas with high virus pressure.

At research stations, scientists use large, expensive screen houses covered with quality netting to protect disease-free planting material that comes from tissue culture laboratories. Recognizing the need for community-level vine multipliers of basic seed[1] to have better and more affordable access to quality, disease-free ('clean') stocks of planting material, the idea of using a much smaller net tunnel with the same quality netting as a screen house emerged. This is one of the potential ways to increase farmer access to quality sweetpotato planting material in high virus pressure areas.

Since 2009, CIP and its partners have been researching the development and use of net tunnels to increasing accessibility to high quality seed in Ethiopia, Kenya, Mozambique, Nigeria, Rwanda, Tanzania, and Uganda. We have learned that the technology can be successfully used by better resourced, trained farmers, to maintain and produce high quality basic seed for two to three years. In some locations, the tunnels themselves have become the symbol of availability of quality seed. The use of net tunnels only makes sense in high virus pressure areas. In areas with low pest and disease pressure, maintaining basic seed in isolated open fields is more profitable.

The objective of the net tunnels is to reduce the exposure of sweetpotato plants to aphids and whiteflies which transmit various viruses. Therefore, it is important to:

- Limit the number of times the net tunnels are opened. The net tunnel should be closed after planting and opened only during harvesting or when weeding is necessary.
- Avoid damaging the net, and mend any holes as soon as they appear. Damage to the net material (e.g. holes) provides an entry point for aphids and whiteflies.
- Identify period of peak demand for planting material and plan the multiplication cycle for pre-basic, basic, certified seed, and quality declared seed accordingly.

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[1] "Seed" for sweetpotato are the cuttings from the vines of sweetpotato plants used as planting material. Pre-basic seed is the generation of seed directly derived from breeder seed multiplied under the management of research centres, in screen houses. **Basic seed** is the generation derived from pre-basic and multiplied in net tunnels at the farmer's level or in isolated open fields in areas with low pest and disease pressure.

This guide provides the steps for constructing a simple tunnel at the farm level and instructions on how to manage the material in the tunnel to ensure a supply of high quality basic planting material, with little or no virus infection.

Options for net tunnel design

Based on feedback and experiences in different countries, below are three options to choose from, listed from least to most expensive.

1) Flexible wooden sticks such as bamboo with the end-tie method

Advantages:

- All materials for constructing the frame are locally available
- Cheapest option
- Can be constructed on site

Disadvantages:

- Wood susceptible to termite attack and weather vagaries
- Least durable frame of the three options
- Permanently fixed – not movable once constructed (it is not re-usable)
- Can cause deforestation of young growing trees
- Wooden sticks can break when bending is not done carefully

2) PVC pipes for frame with zipper or PVC clothing line closing method

Advantages:

- PVC pipe is easy to bend
- Cheaper than reinforcing bars or rods
- Less wear and tear on the netting compared to using wooden stick
- Can be constructed with local labor
- Durable and not damaged by termites

Disadvantages:

- PVC is more expensive than wooden sticks and sometimes not easily available
- Iron pegs require a hack saw to cut
- PVC pipes can lose shape over years under temperature fluctuations

3) Reinforcing bars or rod for frame with full-length zipper closing method

Advantages:

- Most durable of the three options
- Does not use binding wire which can damage the netting material
- Can be moved easily as a unit to different sites

Disadvantages:

- Iron rods are more expensive than PVC and wooden sticks
- Iron rods must be painted to avoid rusting
- Iron rods need to be welded prior to moving to the site
- Not user-friendly for irrigation with water cans

Design of net tunnel

The recommended standard size of one net tunnel is:

Height	1.4 meters in the middle
Length	3 meters
Width	1.8 meters

Larger tunnels can be built, but the above size is very stable against wind and other weather factors.

Materials required for constructing a net tunnel

Insect proof net

Below you will find the measurements needed for the different sides of the net tunnel.

Option 1

Top cover	4 m x 3.0 m
Front end	2 m x 2 m
Back end	2 m x 2 m
Total	20.0 m^2

Options 2 and 3

Top cover	4 m x 3.2 m
Front end	2 m x 1.7 m
Back end	2 m x 1.7 m
Total	19.6 m^2

The most cost-effective way to purchase netting is in rolls. The equivalent of OPTINET 50™ mesh size netting sold in Kenya is recommended. A roll measuring 100 m x 3 m can make 15 net tunnels and one measuring 100 m x 4 m can make 20 net tunnels. Other insect proof nets can be explored where OPTINET 50™ is not available. For instance, in Tanzania Agronet™ produced by A to Z Textile Mills Ltd can be used. A roll measures 30 m x 5.5 m and can make six net tunnels.

Remaining materials needed by option choice

Option 1

Binding wire for tying body frame	5.0 m
Elastic wooden or bamboo sticks[2]	30, each 3.6 m long with a diameter of 4 cm
Manila string for tying ends of netting	11.5 m

Option 2

Binding wire for tying pipes together for frame	5.0 m
PVC pipes	8, each 5.1 m long, 2 cm or ¾ inch diameter
Zipper for closing (two headed)	1.5 m
Small lock for zipper	
Iron pegs from reinforcement rod	16, each 20 cm long, 1.3 cm or ½ inch diameter
PVC clothing line to attach netting to frame on each end	6 m

Clothing line made of copper wires covered with a PVC coating can be used to bind the opening shut. The wires make the line strong, whereas the PVC coating protects it from rust.

Option 3

Reinforced iron rods	6, each 35 ft. or 10.7 m, 10 mm diameter
Long zipper for closing one side	5.2 m
Small lock to attach zippers	

Please make sure that zippers used are heavy duty, of high quality and will not rust. Prior to fitting the net covering, the zippers should be firmly tailor-sewn onto the net.

[2] Wooden sticks can be coated with used engine oil to reduce risk of termite damage

Construction of the net tunnel

STEP 1 • Site selection

Select a site that is:

- Near a permanent source of water for year-round availability of water for irrigation
- Non-steep and level land to avoid water run-off when irrigating
- Safe from risk of theft, vandalism, or damage by livestock, i.e. as close to one's home as possible. New net tunnels attract curious neighbors! Can be fenced to ward off livestock and curious children
- Easily accessible for regular management and monitoring activities
- Free from shade to allow maximum penetration of sunlight and rainwater, but avoid windy areas which may facilitate mite infestations
- Not heavily infested with weeds especially perennial weeds such as *Digitaria scalarum* or couch grass. Sites with spear grass should also be avoided
- Not close to an old sweetpotato crop which may harbor virus vectors
- Not be exposed to water run-off coming from old sweetpotato fields. As the net tunnel is a multiplication plot for 2-3 years it is necessary to avoid any irrigation or run-off source of contaminants (e.g. bacterial diseases) from the old fields

STEP 2 • Site and bed preparation

- Clear the area of weeds for an extended area of 20 m around the proposed net tunnel sites
- Plan on one net tunnel per variety to maintain varietal purity. Planting two varieties may also increase virus infection rate and competition effect. If the varieties have different growth rates the vigorous one might suppress and kill the slower one
- The size of the bed for each tunnel should be 2 m wide by 3.5 m long
- If working in a marshy area, prepare raised beds (40 cm high)
- If in an area that requires frequent irrigation, prepare a basin-like bed (20 cm deep)
- Measure out an area of 1.8 m by 3 m for the tunnel placement
- Mix in well-decomposed organic manure at a rate of three 20-liter (by volume) buckets per 1.8 by 3 m bed near planting time

STEP 3 • Constructing the frame

Option 1 • Using flexible wood or bamboo sticks

- Use 3.6 m long elastic wooden sticks (Figure 1), bend them and push them into the ground about 20 cm deep
- As shown in Figure 2, the distance between the sticks on the sides should be 50 cm
- Put two vertical 1.7 m wooden sticks at each end (front and back) and one 3 m long stick on the top
- Then use iron wire to connect the end sticks and all the bent sticks to the 3 m long central stick to increase stability
- Figure 3 shows how four additional 3-meter long sticks should be placed lengthwise on the sides and tied with iron wire at all the joints with the bent sticks. If such long sticks are not available, two shorter sticks can be joined, but they should overlay by at least 50 cm to be able to make a strong joint

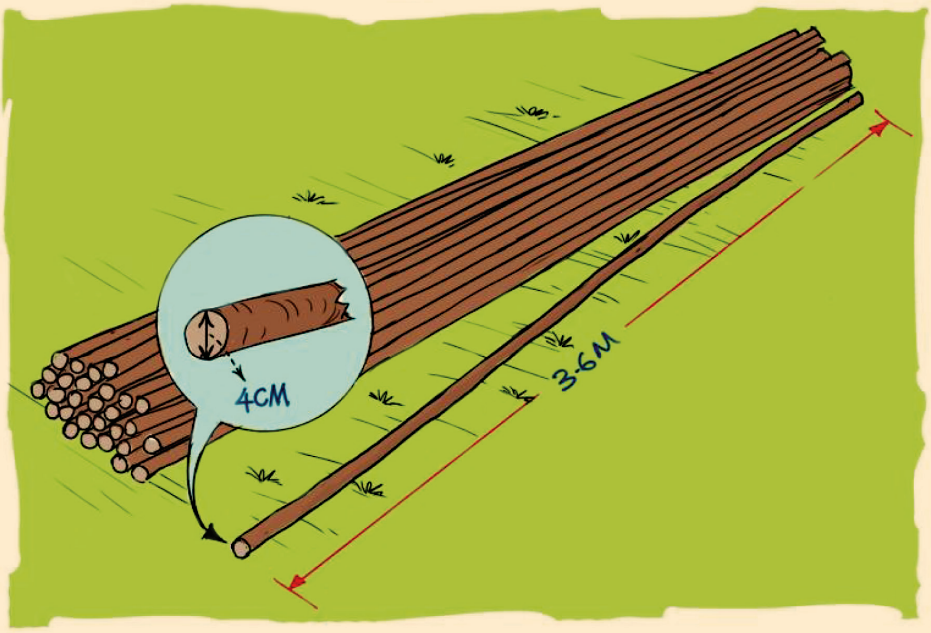

Figure 1. Choice of elastic wooden sticks.

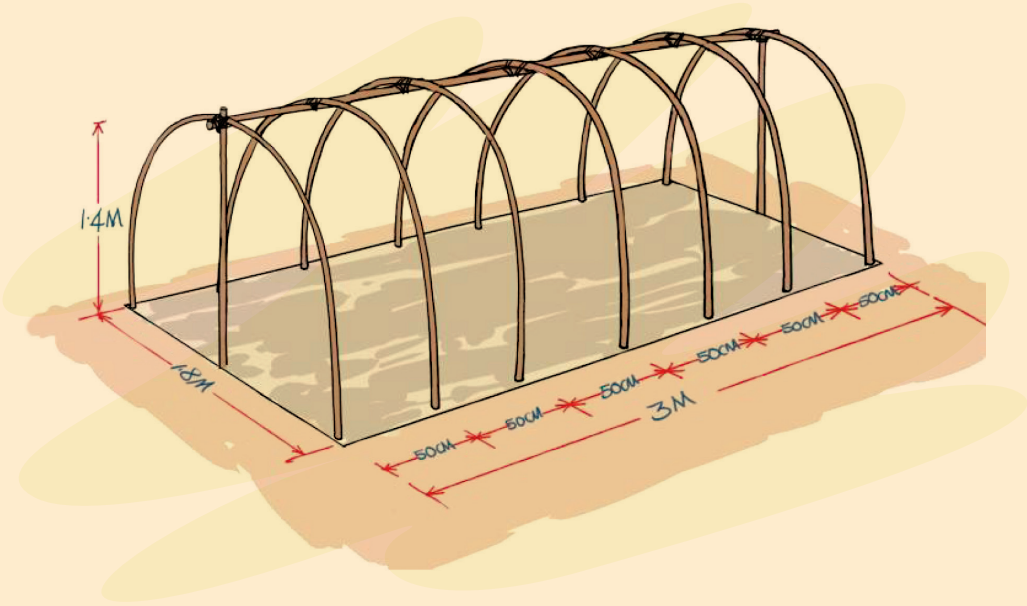

Figure 2. Putting up the structure using the elastic wooden sticks.

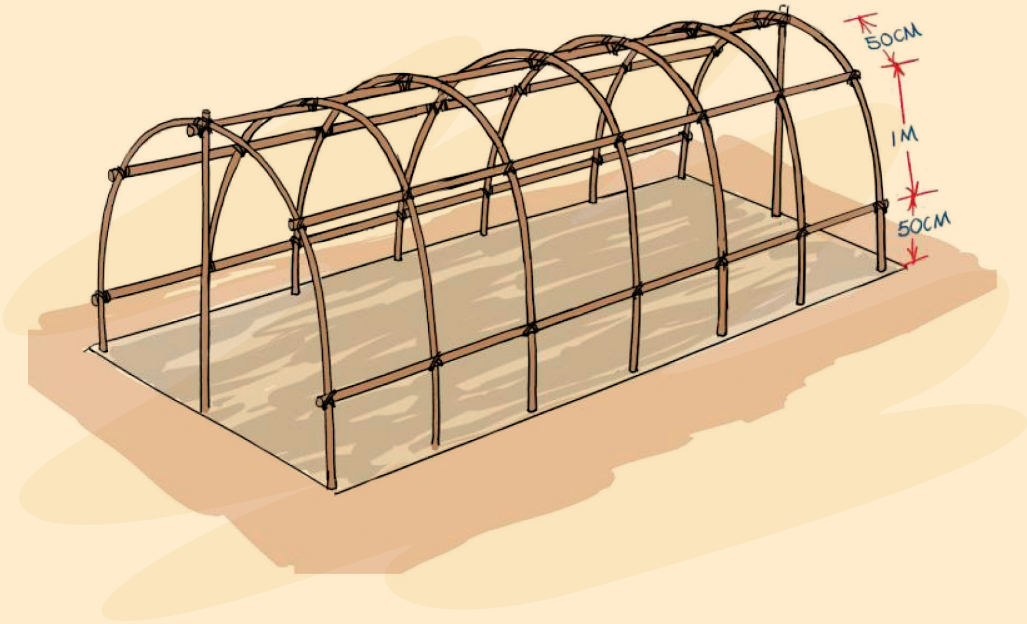

Figure 3. Improving the stability of the structure by reinforcing with more sticks.

Option 2 • When using ¾ inch PVC pipes

- Push ½ inch iron pegs into the soil about 20 cm deep maintaining intervals of 50 cm along the bed. An additional iron peg should be put at the center of both the opening and closing ends. The iron pegs will fit inside the PVC hollow pipes, assuring their stability
- Drive one straight PVC pipe measuring 1.5 m long onto the pegs at both the opening and closing ends. Ten centimeters should be in the ground with the iron peg inside leaving 1.4 m above the ground
- Lay a 3 m PVC pipe on top of the two vertical pipes and fasten with a binding wire
- Drive 3.6 m long PVC pipes onto the iron pegs at both sides of the bed making a smooth curve. Repeat this to make a total of seven arches
- Once the semi-circular structure is completed, put one 3 m long PVC pipe on each side at 80 cm from the ground. Some wait until the tunnel is planted before attaching the horizontal pipe

Plate 1. Constructing a net tunnel frame using PVC pipes. Nigeria. Photo credit: J. Njoku.

Plate 2. A complete net tunnel body frame with 3 m long PVC pipes on each side. Nigeria. Photo credit. J. Njoku.

Option 3 • When using reinforcing rods

- Identify a welder who can construct the frame. Map out on a dirt surface using wooden or iron pegs that show the final circular shape desired (Plate 3). Then the rod is bent fitting through the paired pegs, a process repeated six more times.
- The remaining top, end and side pieces are cut: Two pieces 1.4 m tall, and three pieces 3 m long.
- All the pieces are welded together, not tied with binding wire. The welded frame is transported to the desired site for the tunnel.

Plate 3. Bending the reinforcing rods with the aid of iron pegs planted on the ground. Uganda. Photo credit: S. Namanda.

STEP 4 • Planting inside the frame

- Source cuttings from mother plants that have been tested and are known to be virus-free, e.g. from a research station or tissue culture laboratory. Each vine has bumps called nodes, and each node can generate roots.
- Cut each vine into pieces that are two to three nodes or 10 – 15 cm in length (Figure 4). Note that different varieties have different distances between their nodes.

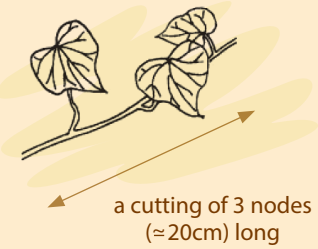

Figure 4. Cutting showing leaves emerging from each node.

- Within a row, leave 10 cm between each plant (Figure 5). If using three-node cuttings, two nodes should go under the soil and if using two-node cuttings, one node should go into the soil. Leave 20 cm between the rows and have 9 rows with 30 plants per row (plant population total of 270).

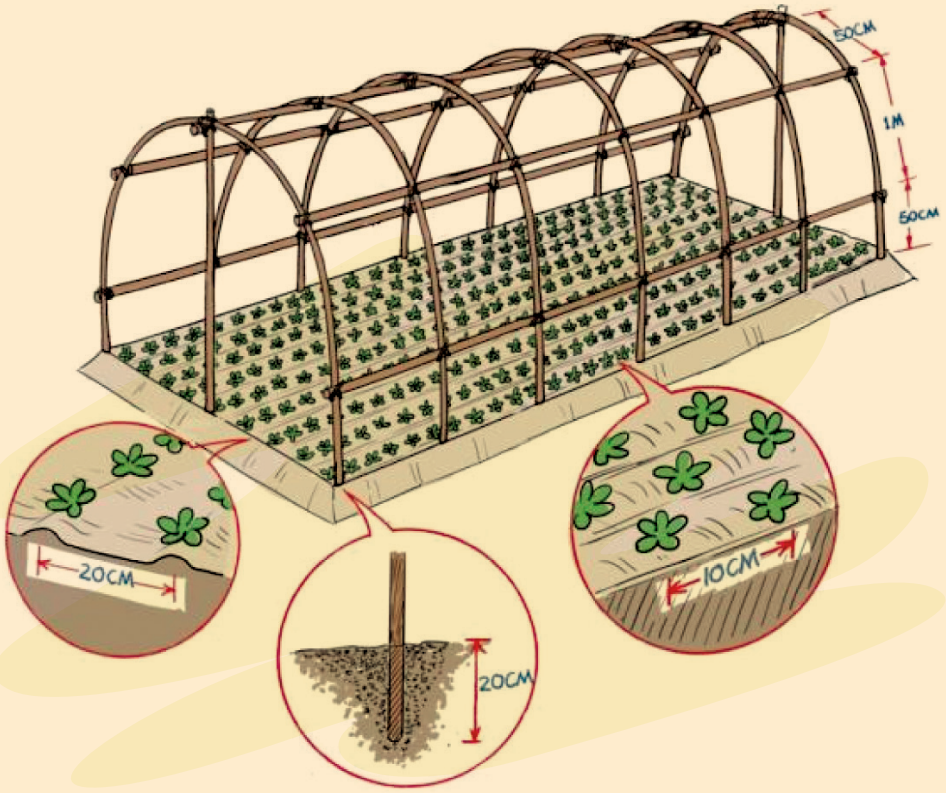

Figure 5. Planting inside the net tunnel.

STEP 5 • Covering the tunnel

- For Option 1, cut the netting into three pieces: two 2 m x 2 m; and one 4 m x 3 m.
- For Option 2: Cut the netting into three pieces: two measuring 2 m x 1.7 m, one measuring 4 m x 3.2 m.
- For Option 3: Bring a competent tailor to measure the dimensions of the iron rod net tunnel frame, noting that 20 cm of extra netting will be needed to go into the soil on each side. The tailor will place the zipper as shown in Plate 4 and sew all the netting pieces together as one unit to fit over the top of the tunnel.

Plate 4. Full-length zipper going around the closing end of Option 3 net tunnel. Uganda. Photo credit: S. Namanda.

- For Options 1 and 2: Put the larger netting on top of the tunnel frame such that there is an extra 20 cm extension of the netting beyond that which reaches the ground on all sides (Figure 6). On each side, where the net tunnel touches the earth, place a pole along the length of the respective side and then cover it with 20 cm of soil, to make it stormproof.

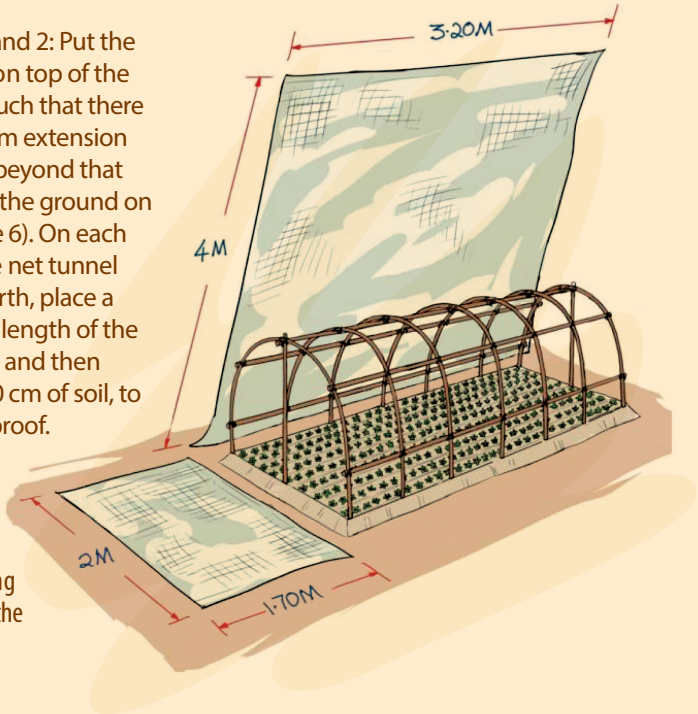

Figure 6. Covering the tunnel with the quality netting.

Plate 5. Larger netting laid on the frame leaving 20 cm on the ground. Nigeria. Photo credit: J. Njoku.

Plate 6. Rolling the netting on a wooden stick before covering with soil. Mwanza, Tanzania. Photo credit: K. Ogero.

- For Option 2, leave at least a 10 cm allowance of extra netting at the front and back to connect with front and back cover.
- For Option 1: Place each end piece on the frame as if it were a diamond (Figure 7). Then using the manila string (each piece 3.5 m long), make a strong knot on each side of the front piece and on the top.

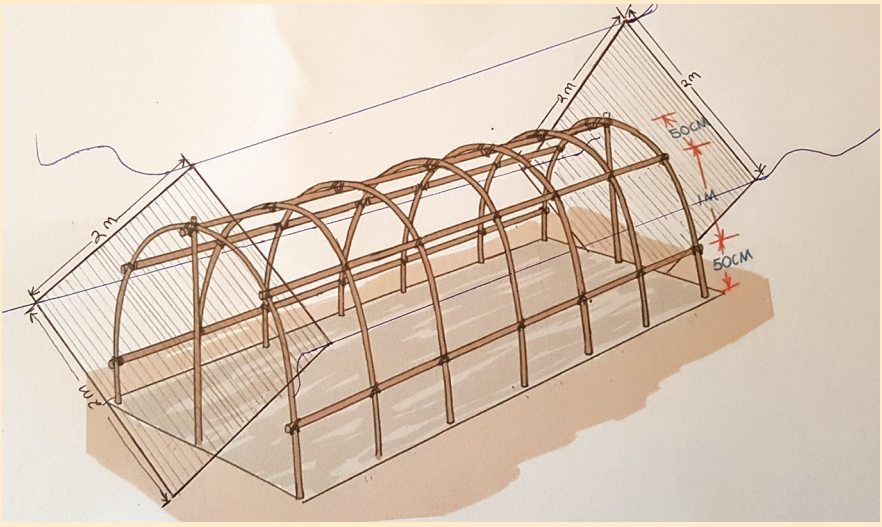

Figure 7. Placing the end pieces on the frame and joining with manila strings.

- Take each string and tie the other end to the same location on the diamond shape piece on the back end (Plate 7). For the bottom part on the front and back ends, take a wooden stick 1.7 m long and roll the netting on top of it, making sure it is level with bottom of the raised bed. Then cover with soil.

Plate 7. Tying the two end pieces together. Mwanza, Tanzania. Photo credit: K. Ogero.

- For Option 2: Holding the end piece on the frame as if it were a square, close the back piece to the main netting piece using the PVC clothing line. Take the 1½ m zipper and front piece to a tailor and explain that you want a semi-circular installation as shown in Plate 8. This design permits a person to enter the net for cutting the vines, without damaging the tunnel. After the tailor has returned the piece, fix it to the main netting and frame using the PVC clothing line.

Plate 8. Front piece with a semi-circular zipper for opening. Nigeria. Photo credit: J. Njoku.

- For Option 3: After placing the net on top of the iron frame, place fired bricks around the outside of the tunnel to retain the shape of the bed and add sand between bricks and the netting to hold the netting firmly on the ground. Use of bricks is optional but netting must be covered to make it stormproof.

Management recommendations

Irrigation

- Irrigate immediately after planting and give light irrigation daily for 15 days until establishment.
- Use a watering can if you have just a few tunnels. Apply water over the top of the net tunnel (i.e., do not open the net tunnel to water). It is best to water in the early morning and late afternoon.
- Use drip irrigation as the scale of production increases.
- Frequency of irrigation should depend on prevailing weather conditions. Do not irrigate during the rainy season if rains are consistent as this might lead to waterlogging.

Fertilizer application

- After every harvest add NPK (e.g. 25:5:5)[3] fertilizer to boost regrowth of shoots from the cut stem at an application rate of 200 g/net tunnel. The fertilizer can be broadcast. This is equivalent to 1 level teacupful of fertilizer.

Pesticide application

- Apply a pesticide such as those containing Cypermethrin before closing and whenever pests are spotted (for example, caterpillars). Any pesticide should be applied per the manufacturer's recommended rates and guidelines for safe use and disposal.

Weed management

- If affordable, black polythene sheet as a mulch is very effective in weed suppression without affecting vine growth.
- Applying a mulch of rice husks after planting can also effectively suppress weeds.
- Uproot all weeds and re-apply the mulch during harvesting.
- In case of a serious weed problem during the growing stage open the net tunnel and remove the weeds but be sure to spray a pesticide before closing.
- Remove all weeds emerging around the net tunnels.

[3] Consult extension staff for locally available fertilizer formulation.

Plate 9. A mulch of rice husks applied in a new net tunnel, Mwasonge village, Mwanza, Tanzania. Photo credit: K. Ogero.

Repair of holes

- Remember it only takes a small hole for aphids or white flies to enter!
- Check the net tunnel regularly (at least once per week) to identify any holes or problems.
- Use a normal household needle and thread used for shoe repair to sew up a damaged net. This can be combined with a small piece of net, cut carefully from the edges of the existing net or sourced from elsewhere. Apply pesticide after repairing the net.

Harvesting

- Cut apical (top) portions of vines, at least 10 cm above the soil level, leaving some nodes on the remaining stems to sprout again.
- If some plants have dried up, use cuttings from the harvested material to fill the gaps. If plant vigor has reduced, uproot all the plants and replant using cuttings from the same material or get new clean planting material from a research station or tissue culture laboratory.
- Harvest at the appropriate time (60 to 80 days after first planting) to avoid intertwining of vines that increases the likelihood of damage to the plants during harvesting. For the next ratoon, you will need to wait 30 to 60 days, depending on weather conditions and management.

Plate 10. Ready-to-harvest planting material in a net tunnel, Nyasenga village, Mwanza, Tanzania. Photo credit: K. Ogero.

Replenishment of net tunnel material using tissue culture-derived plantlets or cuttings

- With good management, the material maintained in the net tunnels can be used for two years after which new generation one cuttings should be planted.

Labeling and record keeping

- Label each net tunnel and open multiplication plot clearly indicating date of planting, source, generation and name of the variety.
- Keep a record of all harvesting dates and number and weight of each variety cut to monitor the productivity of your tunnel.

Plate 11. Well-labeled plot in Mwasonge village, Mwanza, Tanzania. Photo credit: K. Ogero.

Marketing and awareness creation

- Inform local leaders and farmers about the purpose of the net tunnels e.g. through local administrative meetings.
- Encourage farmers to place advance orders for clean planting material.
- Host field days to demonstrate the benefits of using clean planting material to obtain higher yields.

Benefits of using the net tunnel technology

Research on net tunnels began in 2009 in Kenya, where an overall net benefit (determined by yields of roots from net tunnels above that from planting material from open fields) was 839 USD over 33 months. On average, one net tunnel generates 1,750 to 1,980 cuttings per harvest. In 2017, constructing a tunnel ranged from 80 to 130 USD, depending on country conditions and the option selected. This includes planting material. Production costs are heavily influenced by the cost of watering the tunnels and the price of the initial pre-basic seed. Research has expanded to Rwanda, Tanzania, Uganda and Nigeria and reinforced the value of the use of net tunnels in high virus pressure areas. As seen in Figure 8, significant yield increases were seen in Tanzania even after six generations between open field and net tunnel sourced planting material. In Nigeria, after two seasons, yields were still 100-200% higher in net tunnel sourced planting material than open field material (Figure 9). Yield difference benefits are greatest for virus susceptible varieties. In Tanzania, due to the high cost of pre-basic starter material and irrigation, it is recommended to multiply the net tunnel seed twice before selling. By that time, the multiplier will have 31,500 cuttings (30 cm each). In Nigeria, one multiplication after harvesting the net tunnel was sufficient for generating profits.

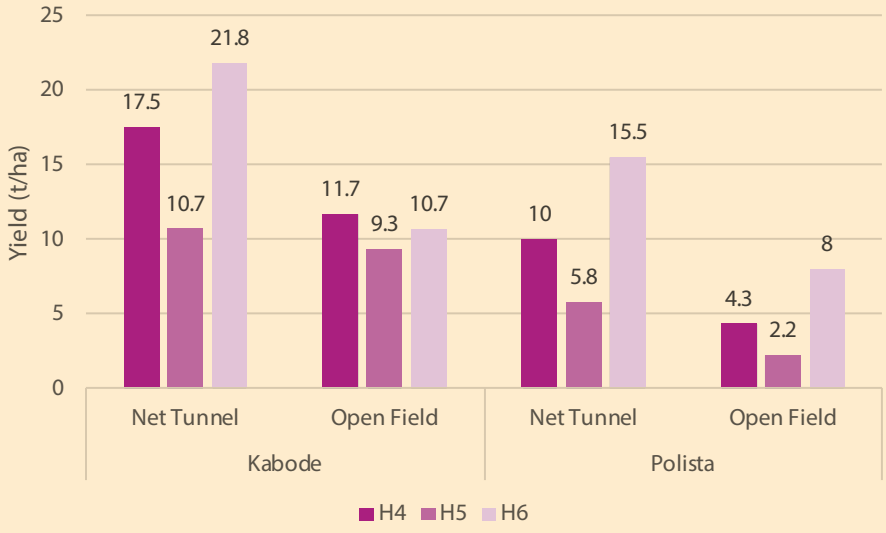

Figure 8. Yield comparison between open field and net tunnel in a high virus pressure (Mwasonge) area in Tanzania for the sweetpotato varieties Kabode and Polista. Source: K. Ogero.

[4] Data presented is from three last generations (H4 – H6) of a study that was conducted over six generations. The aim was to compare yield performance of planting material sourced from the net tunnel and multiplied in the open once with that maintained in the open field throughout.

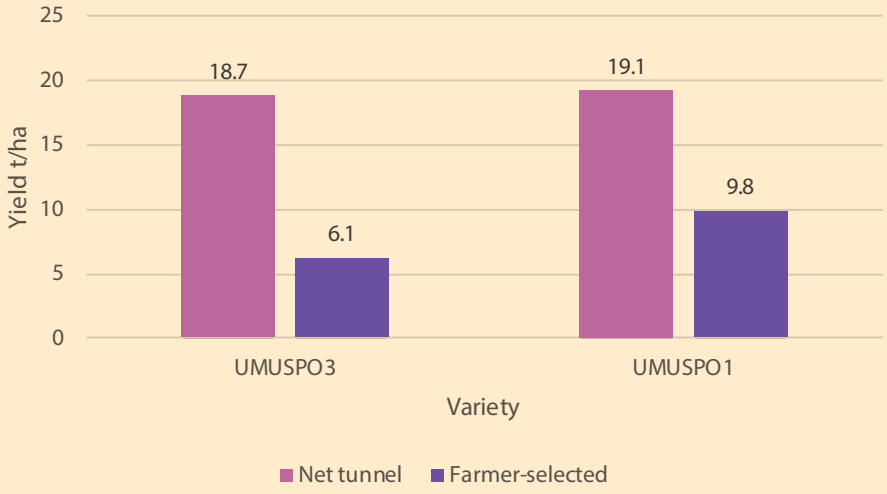

Figure 9. Yield comparison between open field and net tunnel in a high virus pressure (Umudike) area in Nigeria. Source: J. Njoku.

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The International Potato Center (known by its Spanish acronym CIP) is a research-for-development organization with a focus on potato, sweetpotato, and Andean roots and tubers. CIP is dedicated to delivering sustainable science-based solutions to the pressing world issues of hunger, poverty, gender equity, climate change, and the preservation of our Earth's fragile biodiversity and natural Resources.

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