Quality planting material for productivity enhancement in tropical tuber crops

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Abstract

Tropical tuber crops assume importance to ensure food security to ever increasing population in our country. They are considered to be climate resilient crops. Tropical tuber crops include cassava, sweet potato, aroids, yams and minor tuber crops. However, inadequate availability of quality planting material (QPM) is a major handicap faced by farmers for productivity enhancement in these crops. The major constraints faced for quality planting material are low multiplication ratio, lack of availability of healthy planting material, longer time for released varieties to reach farmer, high cost of planting material and difficulty in transportation. Hence quality planting material can be produced by miniset technique, vine cutting technology, micropropagation and true seed production. Among this, mini sett technique is becoming popular in the coming scenario.

Keywords: Micropropagation, miniset technique, quality planting material, true seed production tuber crops, vine cutting technology

Introduction

With the burgeoning population in India, it has been pushed to 102nd rank in the world based on Global Hunger Index 2019, behind most of our neighbouring countries. To feed the ever-growing population in our country, our farmers need to produce 50% more food grains by 2050 (Kumar and Gautham, 2014) [24]. On the contrary, predicted changes in climate may reduce the production of food grains like rice and wheat by 2 to 6% by 2030 and 5 to 11% by 2050 (Wang et al., 2018) [39]. The likely demand – supply gap of major food grains can be effectively bridged by tropical tuber crops (TTCs) which are the concentrated source of carbohydrates.

Tuber crops are the second most important crop after cereals in area and production in the world (Nayar, 2014) [29]. They have high dry matter production per unit area per unit time and are known for their high calorific value. They have wide adaptability to varied soil and climatic conditions and are considered to be climate resilient crops. Diversity of tropical tuber crops include cassava, sweet potato, aroids (elephant foot yam, taro and tannia), yams and minor tuber crops (coleus and arrowroot). In spite of the strides made in crop improvement and release of high yielding varieties of tuber crops, inadequate availability of quality planting material is a major handicap faced by farmers for productivity enhancement in these crops.

Constraints in quality planting material (QPM) production

Quality planting material is the key for successful production of any crop as emphasised by the proverb “As you sow, so shall you reap”. The adoption of high yielding varieties of tuber crops is limited due to lack of adequate quantity of quality planting material. The major constraints in QPM production include:

1. Low multiplication ratio

Multiplication ratio defined as the increase in planting material over what has been planted. For example, in the case of cassava, the multiplication ratio is 1: 10 when compared to cereal crops such as rice and maize with higher multiplication ratio of 1: 500 and 1: 300 respectively. The multiplication ratio in elephant foot yam is 1:4, yams 1:6 and taro 1:20.
2. Lack of availability of healthy planting material
Tuber crops are affected by a wide range of fungal, viral and bacterial diseases which limits the availability of quality planting material. Cassava mosaic disease is a serious problem in the cultivation of cassava which cause yield loss of 20 to 80% (Edison, 2002) [13]. Collar rot of elephant foot yam can cause 20 to 100% yield loss and leaf blight of taro can cause 25 to 50% loss.

3. Longer time for released varieties to reach farmer
When a high new high yielding variety is released, it takes longer time to reach the farmer because of long duration of most of the tuber crops (8 to 10 months) and low multiplication rate.

4. High cost of planting material
In most of the tuber crops, the tuber which is the edible part is also used as planting material. In elephant foot yam, the recommended quantity of planting material is 12 t ha⁻¹ (KAU, 2016) [22] thus increasing the cost of planting material. According to Dibi et al. (2014) [13], in the case of yam, 25 to 50% of the total production cost is for planting material.

5. Difficulty in transportation
The bulkiness of the planting material of the tuber crops, compared to seeds, created difficulty in transportation and germplasm conservation and exchange.

Quality planting material production techniques
The important QPM production techniques in tuber crops are minisett technique, vine cutting technology, micropropagation and true seed production.

I. Minisett technique
Minisett is the optimum reduced size of planting material in tuber crops for rapid multiplication. It is based on the capability of every bud to sprout and grow as a new plant thereby enhancing the multiplication ratio. It a fast and dependable method which can be adopted by farmers also for the production of QPM (George et al., 2006).

a) Minisett technique in cassava
In the conventional system, 15 -20 cm long setts with 10 -12 nodes / buds are used. Only one or two sprouts are allowed to grow for others wasted. By minisett technique, it is possible to utilize the potential of every bud to sprout and grow as a new plant thus enhancing the multiplication ratio. Two node cuttings are taken as minisets using a sharp hack saw blade. Top 1/3 portion is discarded in the traditional system, but it is also utilized in minisett technique. Tip of the stem about 5 -6 cm long with about 4 node is carefully cut and placed in water to prevent dehydration. The minisets are first planted in nursery. Select well drained location for nursery with 35% well drained location for nursery with 35% shade provided shade net. Prepare raised beds in nursery. Selec

b) Minisett technique in elephant foot yam
Elephant Foot Yam (Amorphophallus paeoniifolius) an underground stem tuber, is one of the most popular tuber crops, extensively used as a favorite vegetable by millions of people in India. In Elephant Foot Yam (EFY), edible corm is used as seed corm. Whole corm or corm pieces weighing 1 kg is used as planting material (KAU, 2016) [22]. The multiplication ratio is low in elephant foot yam is 1: 4. So minisett technique is being adopted in EFY.

Small corm pieces weighing 100g are used as minisett which are planted directly in main field. For multiplication, pits are taken at a spacing of 60 cm x 45 cm. A total of 37,000 minisets could be planted in 1 ha as against 12345 setts ha⁻¹ in the conventional system. Planting time and other operations as in the conventional system. Minisett produce corms of 500 -1500 g. These could be used as seed corms for producing minisets or commercial seed production or food purpose. Multiplication ratio is enhanced from 1:4 to 1:15.

Performance of minisett planted elephant foot yam var. Sree Padma was evaluated with different size of planting material and different spacing. Nath et al. (2007) [20] reported corm pieces weighing 200g planted at a spacing of 50 x 50 cm gave highest yield of 658.75 g plant⁻¹ and 26.35 t ha⁻¹. Isaac, et al. (2012) obtained the highest corm yield of 83.39 t ha⁻¹ when minisett weighing 100 g was planted at a spacing of 60 cm x 45 cm. But
plant$^{-1}$ yield was higher for conventional sett of 1 kg planted at a spacing of 90 cm x 90 cm.

c) Minisetts technique in taro

In traditional method of taro production, corms weighing 25 to 35 g or mother corms will be used which will be planted at a spacing of 60 cm x 45 cm. A total of seed material required is 1.2 t ha$^{-1}$ of corms (KAU, 2016)\[22\].

Mother corms are cut into cylindrical pieces and then longitudinally to get minisetts weighing 10 g. Minisetts are planted in main field. They are planted in mounds formed over pits at a spacing of 45 cm x 30 cm. All operations as in the conventional system. The multiplication ratio will be enhanced from 1:20 to 1:120.

Faisal et al. (2009)\[13\] studied the effect of planting material in taro using mother corm weighing 40 g, corm pieces weighing 20 g and cormel weighing 10 g. It was found that number of corms and corm yield plant$^{-1}$ produced by these treatments were on par. But higher cormel yield ha$^{-1}$ were produced with mother corm weighing 40 g and mother corm pieces of 20 g.

d) Minisetts technique in yams

Yams (Dioscorea spp.) are grown in India since very ancient times and D. alata is said to be of Indian origin. Dioscorea rotundata is a native of West Africa while D. esculenta could be of Burma or Indo-China in origin.

In traditional method of yam production, in case of greater yam and white yam tuber piece 250 g was planted in pits or mounds planted at a spacing of 1 m x 1 m. Thus seed material required for 1 ha is 2.5 t ha$^{-1}$. In the case of lesser yam, tuber weighing 100 to 150 g is planted in mounds at a spacing of 75 cm x 75 cm. Thus seed material required for 1 ha is 1.8 to 2.7 t ha$^{-1}$ (KAU, 2016)\[22\]. Paul et al. (2016)\[33\] found that mini tubers must have at least 100 - 300g.

So minisset technique in yams was adopted for rapid and large scale multiplication. Principle involved in this is that any section of tuber capable of developing buds and sprouting provided it has a portion of the periderm (Onwueme, 1973)\[31\]. Pre-sprouting of minisetts in nursery for the success of yam minisset technique was found out by Otoo et al. (2001)\[32\].

The yam tuber is cut into cylindrical / disc like pieces about 5 cm thick and then cut longitudinally to get minisset weighing 30 g. They are spread out under light shade for 1 hr with cut surface facing up. They are planted in nursery beds with 35% shade. Minisetts sprouts within 2 - 3 days. They are transplanted at 3 - 4 leaf stages preferable on ridges at spacing of 60 cm x 45 cm. All other operations as in the conventional system. Minisetts produce tuber of 300 g – 1 kg. Multiplication ratio is from 1:6 to 1:24.

Isaac (2013)\[19\] studied effect of different growth media on sprouting of greater yam minisetts (30 g) planted in trays (40 cm x 28 cm). It was found that minisetts treated with cowdung slurry and planted in soil as growth media gave 100% sprouting at 2 MAP and took less number of days (15.67) for 50% sprouting.

Tuber yield of yam as influenced by sett size of greater yam and white yam was studied using minisset weighing 25g and peel sett weighing 6.25g. It was found that minisset gave better yield than peel sett in both rainy and dry seasons and yield was higher for greater yam in both seasons (Igwilo, 2007)\[16\]. When Greater yam sett weighing 200g planted at a spacing of 90 x 90 cm gave higher net returns and a higher benefit cost ratio of 2.06, when sett size of 100 g, 200 g and 300 g at different spacings were planted in coconut garden. Nedunchezhiyan et al. (2015)\[30\].

II. Vine cutting technology

Propagation using vine cuttings ensures rapid multiplication of planting material in possible tuber crops, sparing the tubers for food purpose, ensuring rapid spread of high yielding varieties and exchange of germplasm.

Vine cutting technology in sweet potato

Sweet potato is propagated by means of vine cuttings. To obtain vine cuttings, a nursery is raised either from stored tubers or from vines of the freshly harvested crop. Vines obtained from nursery are found to be healthy and vigorous resulting in maximum tuber production. Sweet potato vines are produced by planting healthy tubers good quality tubers (75-150g) in the primary nursery and multiplied in the secondary nursery so that 80 kg of tubers is sufficient to produce vine cuttings for planting 1 ha. A study conducted at CTCRI showed that non –marketable grade tubers can also be used for vine production. Apical cuttings are found to be the best and a vine length of 20 - 40 cm with at least 3-5 nodes is found to be optimum for tuber production. The cut vines with intact leaves when stored under shade for two days prior to planting in main field promote better root initiation, early establishment of vines and high tuber yield. The leaves can be removed where the vines are to be transported to distant places to reduce the bulk. A study conducted by Beyene et al., (2015)\[28\] showed that 9-node numbers per cutting with planting of vine cuttings after 2 days of storage duration to maximize their total tuber yield (857.52 q ha$^{-1}$) than immediately planting.

Vine cutting technology in yams

Propagation of yam using vine cuttings is a good option so that entire tuber can be used for food purpose. According to Acha et al. (2004)\[1\], Kikuno et al. (2007)\[23\] and Agele et al. (2010)\[2\], rooted vine cuttings of 20 cm long with 2 to 3 nodes produced mini tubers of 50 to 600 g with a multiplication ratio of 1 : 30.

Vine Cutting technology in coleus

Coleus is propagated from vine cuttings obtained by planting tubers (170 to 200 kg) in a nursery area of 500 to 600 m$^2$ to produce vine cuttings for 1 ha. Vine cutting of 10 to 15 cm from the top portion are taken after 3 weeks for planting in main field.

III. Micropropagation

Tuber crops are prone to attack by various pest and pathogens which cause considerable yield loss and affect the quality of produce. Clonal propagation practiced in these crops results in large scale spread of pest and pathogens. Micropropagation refers to in vitro multiplication of plants using small tissue as explant. This explant can be leaf, root, shoot meristem or nodal cuttings with axillary buds. This method provides and a dependable method to produce a large number of disease free, uniform plantlets in a short time.

Micropropagation in cassava

In cassava, meristem cultures of a wide range of cassava genotypes can be established using 0.1mm size meristem tip excised from shoot tip in Murashige and Skoog medium supplemented with NAA, BAP, GA3 0.1µM each (George, et al., 2006). Raising cassava sets in nursery and using the shoot buds collected from them gave better results in establishing meristem cultures rather that the shoot buds collected directly from field grown plants.
Deepthi et al. (2010)\textsuperscript{10} recommended explant from 3\textsuperscript{rd} node from the top of cassava plant for micropropagation. Nodes from \textit{in vitro} plants sub cultured on MS medium supplemented with 3\% sucrose showed optimal rooting and shooting. According to Asha (2012)\textsuperscript{6} meristem culture and virus indexing in cassava is effective for early detection and elimination of virus production of virus free planting material. Shiji \textit{et al.} (2014)\textsuperscript{18} could produce plantlets having 3 nodes from nodal explant of cassava var. See Padmanabha cultured in MS media with NAA supplement within 1 month. Planting material production from one nodal explant using micropropagation techniques was estimated to be ranging from 16,000 to 17,000 in one year period. Well rooted \textit{in vitro} plantlets in sterilized vermiculite with 4-5 cm length were subjected to hardening for 2 months and transplanted which gave 91\% success.

**Micropropagation in sweet potato**

Meristem culture of sweet potato was done to produce virus free planting material. Considerable yield loss upto 50\% was reported in sweet potato due to sweet potato feathery mottle virus. So meristem culture was done in sweet potato using meristematic tips of axillary shoots having 0.4mm to 0.8 mm length cultured in MS medium developed into complete plants in 20 to 50 days and produced 47\% virus free planting (Alconero, \textit{et al.}, 1975)\textsuperscript{14}. Wondimu (2012), produced multiple shoots from nodal explants of sweet potato and \textit{in vitro} grown shoots produced plantlets which were 99\% free from all viruses.

**Micropropagation in elephant foot yam**

In EFY also, yield loss due pest and pathogens has been reported. Mosaic disease can cause an yield loss of 30\% and collar rot 20 to 100\% (Edison, 2002; Misra and Jeeva, 2006)\textsuperscript{12, 25}. Kamala and Maheshkumar (2014)\textsuperscript{21}, standardised microplant production of elephant foot yam using lateral buds excised from cormels which could be transplanted to the field within 7 months. According to Anil \textit{et al.} (2012)\textsuperscript{5}, Plant development through corm like structures (CLS) from petiole explants is useful for large scale production of plantlets Petiole slices were cultured in MS medium with BA and NAA supplement which produced callus in four weeks. Explants were maintained in the medium and adventitious shoot buds, roots and CLS were initiated as plantlets were obtained from CLS in 4 to 6 month time. Callus induction and CLS formation was slow and poor with explants from Corm.

**Micropropagation in taro and tannia**

Yield loss due to leaf blight of taro was reported to be 25 to 50\% (Misra and Jeeva, 2006)\textsuperscript{29}. Production of virus free plantlets were done in taro and tannia using cormel tip and meristem cultured in MS medium supplemented with NAA and BAP (1.0\%M) (Unnikrishnan, 2006)\textsuperscript{38}.

**Micropropagation in yams**

For production of virus free plants, \textit{in vitro} culture using meristem tip or nodal explants of vine or tuber sprouts was done. In greater yam and white yam, MS medium supplemented with NAA (1 \, \mu M) + BAP (2 \, \mu M) was found effective while in lesser yam, MS medium with NAA (1 \, \mu M) + BAP (10 \, \mu M) was found effective (Unnikrishnan, 2006)\textsuperscript{38}.

**Micropropagation in coleus**

Nodal explants of coleus could be established with root and shoot development in MS medium and further micropropagated on the same medium.

**IV. True seed production**

True seed production is limited in tuber crops due to many reasons such as rare flowering, self-incompatibility, protogyyn, male sterility and poor seed set. However, true seed production has been attempted in cassava. The propagation of cassava through true seeds rather than by clones is a promising option due to its manifold advantages such as enhancing the multiplication rate, keeping the dreaded cassava mosaic disease (CMD) under check, longer seed viability, ease of storage and transport. The rate of sexual propagation could be 20 times higher than traditional clonal propagation.

When true seeds produced by crossing CMD resistant exotic accession MNga-1 and a promising cultivar “Ambakadan” with profuse fruit setting and male sterility and used for further propagation, Rajendran, \textit{et al.} (2015) observed that tuber yield of first clones (C\textsubscript{1}) was significantly superior to that of the seedlings. However, propagation of cassava through true seeds has not become popular because plants raised from seeds exhibit high heterogeneity which is not acceptable by the farmers.

<table>
<thead>
<tr>
<th>Method of production</th>
<th>Starting material</th>
<th>Rate of multiplication</th>
<th>Product</th>
<th>Quality of produce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>200 – 500 g tuber piece</td>
<td>1: 4 – 1: 8</td>
<td>Ware and seed tubers</td>
<td>Low</td>
</tr>
<tr>
<td>Minisetts technique</td>
<td>25 – 100 g tuber piece</td>
<td>1: 30</td>
<td>Seed tubers</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Micro sets / Micro tubers</td>
<td>&lt;10 g tuber piece</td>
<td>1: 90</td>
<td>Seed tubers</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Tissue culture</td>
<td>meristem</td>
<td>1: 1800</td>
<td>Micro tubers and plantlets</td>
<td>High</td>
</tr>
<tr>
<td>Vine cutting</td>
<td>Single node vine cutting</td>
<td>1: 900</td>
<td>Micro tubers and mini tubers</td>
<td>Low to medium</td>
</tr>
</tbody>
</table>

**Minisets for homestead cultivation of tubers**

Isaac \textit{et al.} (2015)\textsuperscript{117} has done the evaluation of minisets as planting material for homestead cultivation of tuber crops. Cassava, tannia, taro, greater yam and elephant foot yam in grow bags produced satisfactory yields of 0.31 to 2.64 kg plant\textsuperscript{1}. Growth, canopy development and yields were appreciable in greater yam, tannia, taro and elephant foot yam while in cassava tuber development and weights were limited by the size of the bags. Poor emergence and establishment of the minisets also proved disadvantageous. Elephant foot yam, tannia and taro were most suited for grow bag cultivation and miniset technology could well be popularized in the homesteads as these require only smaller planting materials, lesser space and fit well in the small gardens of even urban or peri urban homesteads.

**Protocols / Standards for Quality Planting Material Production**

There are certain protocols for quality planting material production given out by Tanwar and Singh, 1988\textsuperscript{137} and FAO, 2006\textsuperscript{144}. It includes : use of healthy and disease free initial planting material, properly equipped laboratory and green

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\textsuperscript{1} Unnikrishnan, 2006
house facilities, selected site for nursery and field should be free from contaminants and volunteer plants and with irrigation and drainage facilities, judicious use of inputs like nutrients and water, regular monitoring of pests and diseases and rouging of infested plants and off types, harvesting at correct maturity stage and proper labelling and storage of planting material. Standards for healthy planting material of different tuber crops have been formulated by CTCRI (2017) [9].

Table 2: Standards of healthy planting material (CTCRI, 2017) [9]

<table>
<thead>
<tr>
<th>Characters</th>
<th>Cassava</th>
<th>Cassava mini sett</th>
<th>Sweet potato</th>
<th>Elephant foot yam</th>
<th>Taro/Tannia</th>
<th>Yam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purity</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Planting material size and features</td>
<td>&gt;5 number of nodes in 20 cm length and 2-3 cm of stem diameter</td>
<td>2 noded settts from meristem derived stems. &gt;2 number of roots and 2-3 fully opened leaves</td>
<td>&gt;6 number of nodes in 20 cm vine</td>
<td>Corms of 500-1000g size</td>
<td>Corms of 34-45g size</td>
<td>Corms of 200-500g size</td>
</tr>
<tr>
<td>Moisture</td>
<td>60%</td>
<td>--</td>
<td>--</td>
<td>60-70%</td>
<td>60-70%</td>
<td>60-70%</td>
</tr>
<tr>
<td>Pest and diseases</td>
<td>Free from pests and diseases</td>
<td>Free from pests and diseases</td>
<td>Free from pests and diseases</td>
<td>Leaf blight &lt;0.5%</td>
<td>Corn rot &lt;0.5%</td>
<td>Virus &lt;1%</td>
</tr>
</tbody>
</table>

Tropical tuber crops are considered as “Future Crops” in the context of climate change to ensure food security to ever increasing population. Varietal wealth is available in these crops. Lack of availability of quality planting material is a major stumbling block in the adoption of HYV especially due to low multiplication rate. Popularization of rapid multiplication of quality planting material through minisett technique ensures productivity enhancement in these crops.

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