International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(4): 1931-1936

Received: 22-05-2020
Accepted: 24-06-2020

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Quality planting material for productivity enhancement in tropical tuber crops

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DOI: https://doi.org/10.22271/chemi.2020.v8.i4t.9912

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 minisett technique, vine cutting technology, micropropagation and true seed production. Among this, minisett technique is becoming popular in the coming scenario. Standards for healthy planting material of different tuber crops have been formulated by CTCRI (2017) [9]. By adopting proper technology, it will be able to increase the production of tuber cops to meet the ever-growing population.

Keywords: Micropropagation, minisett 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) [12]. 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) [11], 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 -20cm 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 minisetts using a sharp hack saw blade. Top ⅓ rd 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 minisetts are first planted in nursery. Select well drained location for nursery with 35% shade provided shade net. Prepare raised beds in nursery with convenient length and breadth and height of 20cm. Two node cuttings are planted end to end horizontally 5 cm deep with buds facing either side at a spacing of 5cm between rows. Growing tips/ the 4 noded topsetts are planted vertically at a spacing 5cm x 5cm to prevent dehydration. Irrigation is provided with micro sprinkler. Minisett sprout in a week`s time. Weekly spray of insecticide is to be done to control white flies. Minisett will be ready in 4 – 5 week time. Main field should be thoroughly prepared and FYM applied and ridges of 30cm height are taken at 45 cm apart. Minisett are carefully uprooted and planted on ridges at spacing 45 cm x 45 cm. The plants establish in weeks' time. All other operation as in the conventional systems. About 60,000 cassava stems and upto 80 t of tuber could be harvested from 1 ha. Multiplication ratio is enhanced from 1:10 to 1:60. (George *et al.*, 2004) [15].

Isaac (2011) [18] obtained the highest $plant^{-1}$ yield of cassava (5.2 kg $plant^{-1}$) with conventional setts of 15 cm long planted at spacing of 90 cm x 90 cm and the highest benefit cost ratio (BCR) of 4.24 with 2 noded minisetts planted at 45 cm x 45 cm spacing. There was no incidence of cassava mosaic virus (CMV) in 2 noded minisett crop as compared to conventional method where CMV was reported to be 2.4% and 4.8% at two and four months after planting respectively. Yadav *et al*. (2014) [41] also reported higher net income from cassava by using minisett as planting material. But BCR was slightly higher (2.71) for conventional sett system which might be due to cost of nursery involved in minisett technique. In order to reduce the cost of nursery involved in minisett technique, minisetts may be planted in portrays filled with coirpith, which enables easier uprooting and transplanting, easy transport, utilization of stem before losing viability and timely planting of the crop. This method is being followed in Instructional Farm, College of Agriculture, Vellayani for distribution of planting material of cassava.

Chickwado (2012) [8] developed a technology for rapid multiplication of cassava. He used 2 node cuttings which are planted in nursery and then transplanted and 3 node cuttings which were directly planted in the field. With efficient field management, the cassava stems were ready for initial harvest six months after planting. The roots were not harvested with the stems; rather, they are left underground to decay and nourish the ratoons emerging from the stumps of the harvested stems. The ratoons were allowed to grow and yielded even more stems than the initial stakes planted in the next 6 months after first harvest. Thus the multiplication ratio was found to be on an average 1: 53 from same area within one year.

Nahar *et al.* (2012) [27] evaluated the performance of mini-cuttings of 5 cm length. The mini-cuttings were pre sprouted for a month in polybags before being transplanted to the field. When the plants were harvested at 12 months, the mini cuttings and normal cuttings of 25 cm length gave comparable tuber yield and starch content.

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 minisetts 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 minisetts 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 plating material and different spacing. Nath *et al.* (2007) [28] 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 83.19 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 90c m x 90 cm.

c) Minisett technique in taro

In traditional method of taro production, cormels 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 cormels (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 cormels 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) Minisett 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 250g was planted in pits or mounds planted at a spacing of 1m x 1m. 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 minisett 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 minisett 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 minisett 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 minisett weighing 25g and peel sett weighing 6.25g. It was found that minisett 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) [7] 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 setts 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) [10] recommended explant from 3rd node from the top of cassava plant for micropropagation. Nodes from *in vitro* plants sub cultured on MS medium supplemented with 3% sucrose showed optimal rooting and shooting. According to Asha (2012) [6] meristem culture and virus indexing in cassava is effective for early detection and elimination of virus production of virus free planting material. Shiji *et al*. (2014) [36] could produce plantlets having 3 nodes from nodal explant of cassava var. Sree 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 *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 meristamatic 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, *et al.*,1975) [4]. Wondimu (2012), produced multiple shoots from nodal explants of sweet potato and *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) [12, 25].

Kamala and Maheshkumar (2014) [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 *et al.* (2012) [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 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) [25]. 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 (1.0µM) (Unnikrishnan, 2006) [38].

Micropropagation in yams

For production of virus free plants, *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 µM) + BAP (2 µM) was found effective while in lesser yam, MS medium with NAA (1 µM) + BAP (10 µM) was found effective (Unnikrishnan, 2006) [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, protogyny, 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, *et al.* (2015) observed that tuber yield of first clones (C_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 1: Comparison of different propagation methods in yams (Aighewi *et al.*, 2015) [3]

Method of production	Starting material	Rate of multiplication	Product	Quality of produce
Traditional	200 – 500 g tuber piece	1: 4 – 1: 8	Ware and seed tubers	Low
Minisett technique	25 – 100 g tuber piece	1: 30	Seed tubers	Low to medium
Micro setts / Micro tubers	<10 g tuber piece	1: 90	Seed tubers	Low to medium
Tissue culture	meristem	1: 1800	Micro tubers and plantlets	High
Vine cutting	Single node vine cutting	1: 900	Micro tubers and mini tubers	Low to medium

Minisetts for homestead cultivation of tubers

Isaac *et al.* (2015) [17] has done the evaluation of minisetts 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^{-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 minisetts also proved disadvantageous. Elephant foot yam, tannia and taro were most suited for grow bag cultivation and minisett 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 [37] and FAO, 2006 [14]. It includes : use of healthy and disease free initial planting material, properly equipped laboratory and green 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]

Characters	Cassava	Cassava mini sett	Sweet potato	Elephant foot yam	Taro/Tannia	Yam
Purity	100%	100%	100%	100%	100%	100%
Planting material size and features	>5 number of nodes in 20 cm length and 2-3 cm of stem diameter	2 noded setts from meristem derived stems. >2 number of roots and 2-3 fully opened leaves	>6 number of nodes in 20 cm vine	Corms of 500-1000g size	Cormels of 34-45g size	Yams of 200 - 500g size
Moisture	60%	--	--	60-70%	60-70%	60-70%
Pest and diseases	Free from pests and diseases	Free from pests and diseases	Free from pests and diseases	Collar rot,leaf blight and dasheen mosaic - <1% nematode - <5% Mealy bug - treated	Leaf blight - <0.5% Corm rot - <0.5% Aphids - treated	Virus - <1%

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.

References

1. Acha IA, Shiwachi H, Asiedu R, Akoroda MO. Effect of auxins on root development in yam (*Dioscorea rotundata*) vine. Trop. Sci. 2004; 44:80-84.
2. Agele SO, Ayankanmi TG, Kikuno H. Effects of synthetic hormone substitutes and genotypes on rooting and mini tuber production of vines cuttings obtained from white yam (*Dioscorea rotundata* Poir.). Afr. J. Biotechnol. 2010; 9(30):4714-4724.
3. Aighewi BA, Asiedu R, Maroya N, Balogun M. Improved propagation methods to raise the productivity of yam (*Dioscorea rotundata* Poir.). Food Sec. 2015; 7:823-834.
4. Alconero R, Santiago AG, Morales F, Rodriguez F. Meristem tip culture and virus indexing of sweet potatoes. Phytopathol. 1975; 65:769-773.
5. Anil SR, Siril EA, Beevy SS. *In vitro* propagation strategies for elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). J. Root Crops. 2012; 38(2):97-108.
6. Asha B. Serodiagnosis and standardization techniques for production of virus free planting materials of cassava variety, Vellayani Hraswa. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 2012, 288p.
7. Beyene K, Nebiyu A, Getachew M. Effect of number of nodes and storage duration of vine cuttings on growth, yield and yield components of sweet potato (*Ipomoea batatas* L.). J. Biol. Agric. Healthcare. 2015; 5(22):51-63.
8. Chickwado EK. Cassava stem multiplication technology: a viable option for industry development? National Root Crops Research Institute (NRCRI), Umudike, Nigeria, 2012.
9. CTCRI [Central Tuber Crops Research Institute]. Quality Planting Material Production in Tropical Tuber Crops. Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, 2017, 38p.
10. Deepthi DC. Effect of explant position and sucrose concentration on the *in vitro* regeneration of cassava. J. Root Crops. 2010; 36(2):145-148.
11. Dibi K, Kouakou AM, Yéo JT, Fofana I, N'Zue B, Brou YC. Effects of planting modes on yam (*Dioscorea alata* L.) vine cutting for mini tubers production. Int. J. Sci. 2014; 3:1-8.
12. Edison S. Plant protection problems in cassava in India. In: Proceedings of Seventh Regional Cassava Workshop. 28 October 2002. Bangkok, 2002, 264-270.
13. Faisal SM, Salam MA, Islam MS, Hossain MI. Effects of planting material and earthing-up on yield and yield contributing attributes of mukhi kachu. Bangladesh J. Agric. Res. 2009; 34(2):263-267.
14. FAO [Food and Agriculture Organization], FAO publications, Rome, 2006, 140p.
15. George J, Nair SS, Sreekumari MT. Rapid Multiplication of Quality Planting Materials in Tuber Crops. Central Tuber Crops Research Institute, Sreekariyam Thiruvananthapuram, 2004, 36p.
16. Igwilo N. Seed Yam Production in Nigeria using minisett and peel sett technique. J. Root Crops. 2007; 33(2):104-108.
17. Isaac SR, Dickson VJ, Varghese J. Evaluation of minisetts as planting material for homestead cultivation of tuber crops. Indian J. Agric. Allied Sci. 2015; 1(4):7-10.
18. Isaac SR, Podikunju B, Pillai PS. Evaluation of minisetts as planting material in cassava in Kollam, Kerala. In: Sajeev, M.S., Anantharaman, M., Padmaja, G., Unnikrishnan, M., Suja, G., and Hegde, V. (eds), Climate Change and Food Security: Challenges and Opportunities for Tuber Crops. Proceedings of National Seminar, Sreekariyam, Thiruvananthapuram. Central Tuber Crops Research Institute, Thriuvananthapuram, 2011, 339-341.
19. Isaac SR, Varghese J, Remya N, Krishnan A. Influence of nursery media and mulching on sprouting and growth of greater yam (*Dioscorea alata*) minisetts. J. Root Crops. 2013; 39(2):247-249.
20. Issac SR, Podikunju B, Pillai S. Minisett technology for tuber crops- performance evaluation in coconut based farming systems. In: Muralidharan, K., Jayasekhar, S., and Rakesh, M.K. (eds.), Proceedings of Twenty Second Swadeshi Science Congress, 6-8 November 2012, Kochi. Central Plantation Crops Research Institute, Kasargod, Kerala, 2012, 142-145.

21. Kamala, Maheshkumar. Optimization of *in vitro* regeneration and microcorm induction in Elephant foot yam. Afr. J. Biotech. 2014; 13:4508-4515.
22. KAU [Kerala Agricultural University]. Package of Practices Recommendations: Crops, (15th Ed.). Kerala Agricultural University, Thrissur, Kerala, 2016, 392p.
23. Kikuno H, Matsumoto R, Shiwachi H, Youohara H, Asiedu R. Comparative effects of explants sources and age of plant on rooting, shooting and tuber formation of vine cutting of yams. Japanese J. Trop. Agric. 2007; 51(2):71-72.
24. Kumar R, Gautam HR. Climate change and its impact on agricultural productivity in India. J. Climatol Weather forecasting. 2014; 2(1):1-3.
25. Misra RS, Jeeva ML. Managing diseases on tuber crops. Indian Hort. 2006; 51(6):25-28.
26. Muthuraj R, George J, Ravi V. Seed certification standards for quality planting material production of cassava, sweet potato, lesser yam and taro. J. Root Crops. 2016; 42(1):3-8.
27. Nahar NE, Tan SL. Cassava mini-cuttings as a source of planting material. J. Trop. Agric. and Food Sci. 2012; 40(1):145-151.
28. Nath R, Kundu CK, Majumder A, Gunri S, Biswas T, Islam SJ *et al*. Seed corm production of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst, Nicholson) through mini corm setts in rainfed laterite ecosystem of eastern India J. Root Crops. 2007; 33(1):30-37.
29. Nayar NM. The contribution of tropical tuber crops towards food security. J. Root Crops. 2014; 40(2):3-14.
30. Nedunchezhiyan M, Byju G, Kumar D. Effect of sett size and spacing on growth, yield and economics of greater yam intercropped in coconut garden. Indian J. Hort. 2015; 65(2):248-251.
31. Onwueme IC. The Tropical Tuber Crops: Yams, Cassava, Sweet Potato and Cocoyams. John Wiley and Sons, Chichester, 1973, 248p.
32. Otoo JA, Okoli O, Ilona P. Improved production of seed yam. IITA Research Guide No. 63. International Institute for Tropical Agriculture, Ibadan, Nigeria, 2001, 1-4.
33. Paul OO, Claire K, Jacques D. Effects of planting methods and tuber weights on growth and yield of yam cultivars (*Dioscorea rotundata* Poir.) in Gabon. Int. Res. J. Agrl. Sci. Soil Sci. 2016; 6(3):32-42.
34. Rajamma P, Jayaprakash CA, Mohandas C. Integrated pest management in tuber crops. Indian Horticulture. 2006; 51(6):22-26.
35. Rajendran PG, Mohan C, Sreekumar J. Standardization of true cassava seed (TCS) programme with special emphasis on more homogeneous, CMD resistant progenies. Euphytica. 2005; 142(1-2):13-22.
36. Shiji R, George J, Sunitha S, Muthuraj R. Micropropagation for rapid multiplication in cassava (*Manihot esculenta* Crantz.). J. Root Crops. 2014; 40(1):1-8.
37. Tanwar NS, Singh SV. Indian Minimum Seed Certification Standards. The Central Seed Certification Board, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India, New Delhi, 1988, 388p.
38. Unnikrishnan M. Protocols for quality maintenance in planting material production. In: Byju, G. (ed.), Quality Planting Material Production in Tropical Tuber Crops. Central Tuber Crops Research Institute, Sreekariyam, Thiruvanthapuram, 2006, 87-92.
39. Wang J, Vanga SK, Saxena R, Orsat V, Raghavan V. Effect of climate change on the yield of cereal crops: a review. Climate. 2018; 6:41-47.
40. Wondimu T, Feyissa T, Bedadav G. Meristem culture of selected sweet potato (*Ipomoea batatas* L.) cultivars to produce virus free planting material. J. Hortic. Sci. Biotechnol. 2012; 87(3):255-260.
41. Yadav P, Abraham N, Vinitha V. Frontline demonstration on minisett technique for rapid propagation of cassava in Kollam district. In: Proceedings of Twenty Fourth Swadeshi Science Congress. 6 - 8 November 2014, Malappuram, Swadeshi Science Movement, Thiruvananthapuram, 2014, 38-41.