International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

IJBSM October 2022, 13(10):1064-1075 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3145

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2022.3145

Macropropagation in Banana (*Musa* spp.): Varietal Response to Media and Field Performance of Plantlets Against Suckers

P. R. Manju and P.B. Pushpalatha

Banana Research Station, Kerala Agricultural University, Thrissur, Kerala (680 652), India

Open Access

Corresponding manjupr.nair@gmail.com

0000-0002-6051-9299

ABSTRACT

The experiment was conducted during December 2020 to March 2022 at Banana Research Station, Kannara, Kerala Agricultural University, Thrissur, Kerala, India to evaluate the response of different banana varieties Nendran, Kadali, Rasthali, Neypoovan, Poovan (Palayankodan) and Grand Naine to macropropagation with two different media (sawdust and cocopeat) and to assess the performance of plantlets generated against suckers. The plantain variety nendran took the shortest time for primary (20.33 days) and secondary bud regeneration (14.33 days) with sawdust as media. Total duration from planting to hardening ranged from 75.9 days in Nendran (sawdust media) to 104.3 days in Poovan (cocopeat media). Significantly shorter duration was observed with saw dust in Nendran, Kadali, Rasthali and Grand Naine compared to cocopeat. The cost of production varied with the variety which ranged from ₹ 1.7–4.0 plantlet^{-1} in sawdust to ₹ 3.2–6.3 plantlet^{-1} in cocopeat. Macropropagated plantlets recorded higher bunch weight than suckers in all varieties. There was no significant difference between the 2 with respect to growth characters like plant height, pseudostem girth, suckers plant^{-1}, days to bunching, days to maturity and crop duration across all varieties except for Neypoovan and Poovan. Quality characters like TSS and fruit acidity did not vary between the two planting materials.

KEYWORDS: Apical dominance, benzyl amino purine, cocopeat, macropropagation, sawdust

Citation* (VANCOUVER)*: Manju and Pushpalatha, Macropropagation in Banana (*Musa* spp.): Varietal Response to Media and Field Performance of Plantlets against Suckers. *International Journal of Bio-resource and Stress Management,* 2022; 13(10), 1064-1075. HTTPS://DOI.ORG/10.23910/1.2022.3145.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study..

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 21st June 2022 RECEIVED in revised form on 24th September ACCEPTED in final form on 06th October 2022 PUBLISHED on 19th October 2022

1. INTRODUCTION

In banana, natural regeneration through suckers is comparatively slow (Hussein, 2012). Apical dominance is a major constraint to the sprouting of new lateral shoots (Opata et al., 2020; Rajenimbalkar et al., 2021). A well developed banana corm contains several axillary buds which essentially hosts meristems of different ages and stages of development (Kwa, 2003). Suckers are the most widely used planting material due to its lower cost, lesser field care required, but has the risk of being carriers of pests and diseases, bulky in transportation, lower multiplication rate and chances of variety mix up (Njukwe et al., 2013). Micropropagation assures rapid production of healthy, vigorous and disease-free planting material. However, as a propagation method, it is not an option for small-scale farmers and hence there is a need for cheaper and simpler techniques that increase the sucker multiplication at farm level warranting minimum technical skill (Sajith et al., 2014). Macropropagation is one such cost effective technique where repression of apical meristem stimulate the regeneration of lateral meristem (Tumuhimbise and Talengera, 2018). Studies have shown that there is no difference in agronomic characteristics between *in vitro* plants and macropropagated plantlets. It can be adopted for the production of healthy banana planting material because of its simplicity, low cost and speed (Sadom et al., 2010, Manju and Pushpalatha, 2020). Plant growth hormones like cytokinins which are known to regulate shoot growth (Subbaraj, 2011) are also increasingly employed in macropropagation (Thiemele *et al*., 2015, Kindimba and Msogoya, 2014).

In nature, a large number of elite banana varieties of different genomic groups exist, but only a few are multiplied on a commercial scale. Many of them are extinct or are in the verge of extinction due to non-availability of planting material (Bohra et al., 2013). While India stands first contributing 26% of the world banana production (Archith et al., 2021), the South Indian state of Kerala is home to a wide range of banana cultivars, with an area and production of 0.11 mha and 0.81 mt respectively (Anonymous, 2021). Apart from 'Nendran' which covers 50% of area in the state, other traditional cultivars viz.'Poovan' (Palayankodan), 'Rasthali', 'Njalipoovan (Neypoovan)', 'Kadali' etc. are integrated in the polyclonal system unique to Kerala (Menon et al., 2014). The current plantain and dessert banana farms in the state are insufficient to meet the needs of the population due to lack of good quality plant material. This justifies the use of macropropagation for the multiplication of these varieties. The technology of macropropagation developed by ICAR–National Research Centre for Banana (NRCB), Tiruchirappalli was tested at Banana Research Station, Kannara, Kerala under the ICAR – All India Coordinated Research Project (Fruits) for its standardization in banana cv. Nendran and Grand Naine using saw dust as media (Patil et al., 2016). In banana, both internal and external factors affect sucker production. Intra-clonal variability in suckering habit of different banana clones is also much clear (Bhende and Kurien, 2015). The proliferation of shoots depends on the physiological state of corm, their health status, environment, genetics of the variety (Ntamwira et al., 2017) as well as the media used for initiation (Pavitra et al., 2017). The main objective of the present investigation is to evaluate the response of banana varieties to different media as well as to assess the performance of macropropagated plantlets against suckers.

2. MATERIALS AND METHODS

The experiment was conducted during December 2020 to March 2022 at Banana Research Station, Kannara, Kerala Agricultural University Thrissur, (10° N 76° E), Kerala, India. The trial consisted of two parts, (i) varietal response to different media and (ii) evaluation of macropropagated seedlings in comparison to suckers.

2.1. Varietal response to different media

6 traditional banana varieties cultivated in the state were subjected to macropropagation to study their response to media viz., sawdust and cocopeat for two seasons inside net house with 50% shade under normal temperature. The treatments and treatment combinations are as follows.

2.1.1. Varieties

V_1:Nendran(AAB), V_2:Kadali(AA), V_3:Rasthali (AAB), V_4:Neypoovan (AB), V_5:Poovan(Palayankodan, AAB), V_6:Grand Nain(AAA)

2.1.2. Media

M_1: Sawdust±VAM (30g)±BAP (4 ml, 40 ppm)±*Bacillus subtilis* (30g). (AICRP technology)

M_2: Cocopeat±VAM (30g)±BAP (4 ml, 40 ppm)±*Bacillus subtilis* (30g).

2.2. Treatment combinations

Twelve treatment conditions are as followed V_1M_1, V_1M_2, V_2M_1, V_2M_2, V_3M_1, V_3M_2, V_4M_1, V_4M_2, V_5M_1, V_5M_2, V_6M_1, V_6M_2.

Experimental design was Completely randomized design (CRD) with three replications and 5 corms treatment^{-1}.

2.3. Methodology

2.3.1. Sucker preparation

Healthy sword suckers (1 kg, 2–3 months old) were selected and detopped just above the juncture of the corm and aerial shoot. The remains of roots were removed and external layer of the corm scraped using a sharp knife. After washing in clean water, the ensheathing leaf bases were removed from the pseudostem and detopped just above the juncture of corm and aerial shoot. 6–8 cross cuts were given depending on the size of the suckers and the apical meristem was then removed to a depth of 2 cm. The corms were given fungicide treatment by soaking in Carbendazim (0.2%) for 30 minutes to prevent any soil borne diseases and allowed to dry (Plates 1–5).

2.3.2. Preparation of substrate and planting of suckers

Decorticated and decapitated suckers were planted individually in beds filled with media (2 kg corm^{-1}). Sawdust

Plate 1: Sword sucker preparation

Plate 2: Removal of leaf sheath

Plate 3: Decapitated sucker with cross cut

Plate 4: Decorticated sucker

Plate 5: Carbendazim treatment to corms

was initially moistened and decomposed for 2–3 weeks prior to use. The prepared corms were planted in media completely buried to a depth of 3–5 cm, followed by light irrigation using a rose can. Bioagents (VAM 30 g corm^{-1}+*Bacillus subtilis* 30 g corm^{-1}) were mixed with media prior to planting corms. The phytohormone Benzyl amino purine (BAP, 40 ppm @ 4 ml corm^{-1}) was poured into the cavity left by the removal of the apical meristem at the time of planting followed by complete covering with sawdust (Plate 6).

Plate 6: Planting corms in media

2.3.3. Bud formation and decapitation

Primary plantlets emerged were allowed to grow for 25–30 days. At 3 leaf stage, with a height of 15–20 cm and a stem girth of 2.5cm, they were decapitated, juvenile meristem removed and 4–6 horizontal incisions were given for the young rhizome and covered with sawdust. From each primary plantlet, secondary plantlets developed were allowed to grow for another 20–30 days. Afterwards the secondary plantlets were carefully removed along with the root system and planted in poly bags filled with potting mixture (top soil, cowdung and sand at 1:1:1 ratio) and hardened for 45 days before planting in the field (Plates 7–11).

Plate 8: Corm with primary buds and root system

Plate 9

Plate 10

Plate 9: Decapitated primary buds; Plate 10: Secondary plantlets

Plate 7: Primary buds

Plate 11: Hardened plants

The experiment was repeated twice in 2020–21, each experiment taking a period of four months. Observations were taken on time taken for bud (primary and secondary buds) regeneration from the decorticated suckers. Total number of primary and secondary buds formed at the end of 3rd month after planting was recorded. Duration from planting to hardening were also observed for each variety. Growth characters measured included plant height, pseudostem girth and leaves/ plant in primary and secondary plants. Plant height was measured from the base of the stem to the angle made between the youngest and first open leaf, while girth was measured at 1–2 cm above the collar region while attached to the corm but before weaning. Leaves plant^{-1} was recorded in secondary seedlings at weaning from the mother corm.

2.4. Evaluation of macropropagated seedlings in comparison to suckers

The macropropagated plantlets (secondary) and suckers of each variety were planted in the field and evaluated for one season in a randomized block design (RBD) with ten replications and two treatments. Growth parameters viz., plant height, pseudostem girth, leaves plant^{-1}, suckers plant^{-1}, leaf area were recorded at bunching. Leaf area was calculated by multiplying the product of number of leaves, leaf length and width (at the broadest part of the third leaf from the top (index leaf)) by the factor 0.8 (Murray, 1960). Days to bunching was taken as the number of days from planting to bunching, while days to maturity was recorded as the duration from bunching to harvest. Observations on bunch characters (bunch weight, hands bunch^{-1} and fingers bunch^{-1}) were taken at harvest (full maturity). Middle finger in the top row of the second hand (from the base of the bunch), designated as the index finger or D finger was taken for studying the finger characters viz., finger weight (g), finger length (cm) and finger girth (cm). Fruit quality parameters like TSS and acidity were estimated at ripening (Ranganna, 1986).The data of both experiments were analysed using ANOVA and means compared with least significant differences to determine any significant differences between the treatments (Panse and Sukhatme, 1967). The soil type was laterite, acidic (pH 5.2) with medium to high organic carbon, potassium, high phosphorus levels and deficient in magnesium and boron. The region enjoys a tropical humid climate receiving an average annual rainfall of 2800 mm. Management practices were given as per the Package of Practices Recommendation of Kerala Agricultural University for the crop (Anonymous, 2016).

3. RESULTS AND DISCUSSION

In banana, the leaf bears an axillary (primary) bud at the point of overlapping of the leaf sheath. However, the architecture of the plant is such that several secondary buds occur along the entire length of the base of a leaf sheath. Most of these buds remain dormant and never become suckers in the lifetime of the plant. Through macropropagation, these dormant buds could be activated to produce healthy planting materials within a short time. The entire potential of the corm and suckers could thus be exploited to produce large quantity of healthy planting materials within a short period. The differential response of varieties to macropropagation, and to media are presented below.

3.1. Varietal response to macropropagation and media

Among the 6 varieties studied, nendran was the most responsive in terms of number of primary and secondary buds produced (Table 1). Nendran, Rasthali and Grand Naine produced a greater number of primary buds in sawdust media (Plates 12 and 13), while no significant difference with respect to media was observed for Kadali, Neypoovan and Poovan. In terms of secondary buds weaned, sawdust was found better than cocopeat regardless of the variety which ranged from 12.03 (Rasthali) to 21.03 (Nendran).

Days taken for primary bud regeneration was significantly less in sawdust media for all varieties. Nendran in saw dust took the least time (20.33 days), while Rasthali in

Table 1: Response of different banana varieties to media

Treatment	PB	SBW	DP	DS	D
Nendran+sawdust	10.50	21.03	20.33	14.33	75.90
Nendran+cocopeat	7.33	16.77	32.00	26.33	92.40
Kadali+sawdust	8.33	14.23	33.67	17.00	94.10
Kadali+cocopeat	7.33	12.00	39.33	19.33	102.10
Rasthali+sawdust	6.33	12.03	36.67	17.67	81.90
Rasthali+cocopeat	4.67	10.60	43.67	19.00	90.30
Neypoovan+ sawdust	8.33	17.53	38.67	18.67	91.00
Neypoovan+ cocopeat	7.67	13.30	43.00	19.67	96.30
Poovan+ sawdust	5.33	12.23	34.33	26.67	100.20
Poovan+ cocopeat	4.33	9.93	38.67	26.33	104.30
Grand Naine+ sawdust	8.33	17.50	23.67	24.00	75.6
Grand Naine+ cocopeat	6.33	10.77	32.67	30.33	90.90
SEm±	0.28	0.33	0.42	0.38	4.06
CD (p=0.05)	1.44	1.86	2.53	2.32	5.06

PB: Primary buds; SBW: Secondary buds weaned; DP: Days to primary; DS: Days to secondary; D: Duration (days)

Plate 12:Nendran on macropropagation in sawdust

Plate 13: Grand Naine on macropropagation in sawdust

cocopeat had the maximum (43.67 days) for regeneration of primary buds. Days to secondary bud regeneration ranged from 14.33 (nendran in sawdust) to 30.33 (Grand naine in cocopeat). Media did not make much difference for most of the varieties except in Nendran and Grand Naine, for which sawdust took the shortest time. Total duration from planting to hardening ranged from 75.90 days in Nendran (sawdust media) to 104.30 days in Poovan (cocopeat media). Significantly shorter duration was observed with saw dust in Nendran, Kadali, Rasthali and Grand Naine compared to cocopeat. Plantain variety nendran was found give the best response to macropropagation with saw dust as media. This was in line with the findings of Dzomeku et al. (2014), where plantain was more prolific than dessert varieties in terms of young plants weaned per explant.

Soaking banana corms in synthetic plant hormones is a widely adopted method by small lholder farmers in Africa for raising new planting material (Opata et al.,2020). Cytokinin and auxin work antagonistically and thus an application of cytokinin decreases the apical dominance, while an application of auxin increases the apical dominance. Benzyl amino purine (BAP) is an adenine-based cytokinin popularly used for in vitro induction of axillary and adventitious shoots in banana. With sawdust as media, use of *Bacillus subtilis* in combination with BAP and arbuscular mycorrhizal fungi (AMF) alone or in combination with *Trichoderma viride* increased the regeneration efficiency of secondary bud in banana cv.Bangladesh Malbhog (Sajith et al., 2014). Similar results were also reported in wild banana, *Musa laterita* (Dayarani et al., 2013). Park et al., 2014 examined the response of macropropagation in banana and found that saw dust produced more plantlets corm^{-1} compared to rice hull irrespective of genotypes. Cultivar differences was observed by Ntamwira et al. (2017) in which fewer scarified plantlets were produced for Kisubi (ABB, 3.85), Vulambya (AAA highland cooking type, 3.86) and 'Cavendish' (dessert, AAA, 3.90) when compared to the plantains ('Musheba' and 'Kotina', 5.10). Significant genotypic response observed in the present study could be due to variable ploidy level and genomic complements. Ploidy level influences the size of different plant parts in *Musa* species, but genome complement determines the number of plantlets produced (Bhende and Kurien, 2015).

The phenology of banana is a function of its vegetative growth, determined by cultivar/subgroup specific thresholds (Taulya et al., 2014). Plant height of primary seedlings varied between 20.08 cm (Grand Naine in cocopeat) to 38.94 cm (Neypoovan in sawdust) (Table 2). In the case of secondary seedlings, plant height ranged from 14.12 (Grand Naine in cocopeat) to 24.23 cm (Neypoovan in sawdust). While Nendran, Neypoovan and Poovan exhibited significantly higher plant height of primary plantlets in saw dust, Kadali, Rasthali and Grand Naine did not show any difference between the media. Similar trend was also observed in the plant height of secondary plantlets among

Table 2: Growth characters of macropropagated plantlets in response to variety and media

Treatment	PH*	PH	LV	PG	P
Nendran+sawdust	28.57	21.18	3.08	6.61	3.37
Nendran+cocopeat	21.54	16.82	3.17	7.78	4.55
Kadali+sawdust	31.58	21.08	3.36	5.78	3.27
Kadali+cocopeat	28.84	18.50	3.58	6.06	3.04
Rasthali+sawdust	29.39	21.20	3.00	4.59	3.83
Rasthali+cocopeat	27.36	19.80	3.61	4.60	3.34
Neypoovan+sawdust	38.94	24.23	3.72	5.00	3.27
Neypoovan+cocopeat	33.86	22.50	3.42	5.01	3.33
Poovan+sawdust	30.98	20.52	3.39	4.94	3.79
Poovan+cocopeat	24.21	18.55	3.31	4.62	3.55
Grand Naine+sawdust	21.53	14.77	2.97	6.75	4.38
Grand Naine+cocopeat	20.08	14.12	3.20	6.63	4.48
SEm±	0.61	0.31	0.08	0.09	0.09
CD (p=0.05)	3.42	1.74	NS	0.53	0.52

PH*: Plant height (primary) (cm); PH: Plant height (secondary) (cm); LP: Leaves plant^{-1}; PG: Pseudostem girth (primary) (cm); P: Pseudostemgirth (secondary) (cm) varieties, but their magnitude between the media was only marginal, so as to make a striking difference. Leaves plant^{-1} remined on par between all varieties and media. Varietal variation was observed with respect to pseudostem girth of primary plantlets, while such contrast was not there in secondary plantlets. The stem girth has an important role in the survival rate at hardening stage. Sajith et al. (2014) found that a stem girth of 2.40–2.78 cm showed good survival at acclimatization stage. In the present study, pseudostem girth of secondary plantlets ranged from 3.04–4.48 cm and hence the survival during hardening was appreciably high. Plantlets obtained through macropropagation have the uniformity of micropropagated seedlings while being less prone to post-establishment factors in the field (Njukwe et al., 2013).

3.2. Physico-chemical properties of media

Determination of appropriate substrates based on technical and economic feasibility is a vital aspect of research and key to success in any soilless production system. In general, alternative growing media used were mostly residual materials such as sawdust, cocopeat, distillery wastes, municipal solid waste, sewage sludge, rice hull etc. Eventhough a wide selection of growing media is available, the choice often depends on grower's financial and technical implications. Most growers use substrates that are locally available as it is cheap and reliable (Anonymous, 2013). The properties of different material used as growing media exhibit direct and indirect effects on plant growth and production. Sawdust is widely used as a growth medium component in areas with wood processing industries, because of its low cost, high moisture retention, and high availability (Jung et al., 2017). Cocopeat is light in weight with low shrinkage, low bulk density and has slow biodegradation with longer decomposition time of 10 years (Singh et al., 2015). The physical and chemical properties of the media used in the study were analysed and presented in Table 3.

Table 3: Physical and chemical properties of media used for macropropagation

Sl. No.	Parameter tested	Saw dust	Cocopeat
1.	pH	6.70	6.12
2.	Electrical conductivity (dSm^{-1})	0.46	1.68
3.	Carbon (%)	56.69	37.24
4.	Nitrogen (%)	0.59	0.51
5.	Phosphorus as P_2O_5 (%)	0.18	0.23
6.	Potassium as K_2O (%)	0.28	1.04
7.	Bulk density (g/cc)	0.26	0.35
8.	Total porosity (%)	76.58	75.52
9.	Water holding capacity (%)	74.71	71.03

The initial pH and EC of the media are two important properties of any growing media as they directly influence the availability and indicate inherent nutrient status in the media. Although different plant species (and cultivars) have different pH range for optimal growth, overall, the optimum pH of the soilless media for good availability of essential elements is around 6.0, while an acceptable range of electrical conductivity (EC) of a good soilless media should be less than 1.0 mS cm^{-1}. In the present investigation, while the pH of the media was close to the optimal range, the EC of cocopeat (1.68 dSm^{-1}) was higher than the optimum (Table 3). Electrical conductivity is an index of the presence of total soluble salts in a medium. High EC causes poor shootand root growth. The level of soluble salts that may be tolerated is highly crop specific. Santana et al. (2020) reported that plant height could be affected with the increase of salinity (EC). Reduction in the growth of plants subjected to high EC are directly associated with the reduction in their water absorption due to the decrease in the osmotic potential of the soil solution, caused by the accumulation of soluble salts finally leading to decrease in the absorption of essential nutrients (Munns and Tester, 2008, Iqbal et al., 2014). In the present study, while Nendran, Neypoovan and Poovan showed higher plant height of primary seedlings in saw dust media, Kadali, Rasthali and Grand Naine were on par for the same between sawdust or cocopeat. This shows that sensitivity to salts vary between banana varieties which was corroborated earlier by Santana et al. (2020). Untreated cocopeat is reported to have high K, Na, and EC with limited Ca and N concentrations. Through the use of $Ca(NO_3)_2$, these excessive elements can be minimized while the limited elements can be supplemented. Physical characteristics like bulk density, total porosity and water holding capacity of both saw dust and cocopeat were close to each other and in good proportions to support optimum plant growth. Ede et al. (2015) reported 70% total porosity and 0.8 g cc^{-1} bulk density in 100% saw dust media and observed that these attributes qualify sawdust as well as sawdust plus poultry manure as good growth media for crop seedlings with short nursery lives. Similar results were also reported in cocopeat by Mariyappillai and Arumugam (2021) who found favourable hydrological properties with cocopeat having desirable levels of physical and chemical properties. In contrast, Arenas et al. (2002) reported that utilization of cocopeat as a growing media mixture at higher proportions (>50%) cause immobilization of N which is viewed as an unavoidable consequence of biological activityof microorganisms that consume carbon available in the media. Cocopeat needs to be amended with suitable organic composts so as to maintain optimum nutrient status in growing media for satisfactory growth of plants.

There is no ideal substrate or mixture that can fulfill all the requirements of plant species in all conditions (Di Lorenzo et al., 2013).The present investigation revealed that sawdust as well as cocopeat yielded planting materials of banana, with sawdust performing better on certain parameters and varieties. Both sawdust and cocopeat are biowastes obtained from wood processing and coir industry respectively (Adegoke et al., 2022). Hence it is recommended that local availability, geographic location, plant variety, substrate cost etc. are to be considered while selecting the media.

3.3. Economics of macropropagation

The cost of producing planting material through macropropagation in the experiment is presented in Table 4. The cost plantlet^{-1} varied with the variety and it ranged from ₹ 1.7–4.0 in sawdust and from ₹ 3.2–6.3 in cocopeat. The higher cost in cocopeat is mainly because it was more expensive than sawdust and yields lesser plantlets per sucker^{-1}. The fixed costs in terms of construction of beds, propagation structures etc. were not included as they can be reused. Whatever be the media, the cost of production is much less in comparison to conventional suckers and tissue culture plants. This shows that plantlet production through macropropagation is economical and can be adopted by small and marginal farmers who face difficulty to use tissue culture plants due to higher plantlet cost. Maintaining pest and disease-free mother block would be beneficial to ensure regular supply of quality suckers for macropropagation.

Table 4: Economics of macropropagation and cost comparison among banana varieties

Sl. No.	Variety	Cost incurred to macropropagate one sucker (₹)		No. of plantlets produced from one sucker		Cost of production plantlet^{-1} (₹)	
		Saw dust media	Cocopeat media	Saw dust media	Cocopeat media	Saw dust media	Cocopeat media
1.	Grand Naine	35	55	18	11	1.9	5.0
2.	Kadali	56	76	14	12	4.0	6.3
3.	Rasthali	36	56	12	11	3.0	5.1
4.	Poovan	35	55	12	10	2.9	5.5
5.	Nendran	35	55	21	17	1.7	3.2
6.	Neypoovan	36	56	18	13	2.0	4.3

Cost of one sucker taken for the analysis was as follows, Grand Naine- ₹ 18, Kadali- ₹ 40, Rasthali- ₹ 20, Poovan- ₹ 18, Nendran- ₹ 18 and Neypoovan- ₹ 20. Cost of sawdust used was ₹ 3, while that for cocopeat was ₹ 23 for one sucker. Cost for other inputs like BAP, VAM, Bacillus subtilis, hardening and labour charges was worked out to be ₹ 14 sucker-1. 1 US$ = ₹ 74 (Average value during December 2020)

3.4. Evaluation of macropropagated plantlets in comparison to suckers

3.4.1. Growth characters

Both macropropagated plantlets and suckers performed on par with respect to growth characters like plant height, pseudostem girth, suckers plant^{-1}, days to bunching, days to maturity and crop duration across all varieties except for Neypoovan and Poovan (Table 5). The method of propagation appears to have least effect on these characters indicating that it is genetically controlled trait. Leaves plant^{-1} and leaf area were more in macropropagated plantlets than suckers in all varieties. Production of an optimum number of leaves and leaf area before the onset of flowering is an essential requisite for flowering and proper crop maturity in banana (Barker and Steward, 1962). Leaf is an important index of vigour that influences the consequential yielding capacity of a cultivar (Phukan et al., 2016).

3.4.2. Yield characters

Significantly higher bunch weight was observed for macropropagated plantlets in all varieties when compared to suckers (Table 6). This increased bunch weight was contributed by higher hands bunch^{-1}, fingers bunch^{-1}, finger weight and finger girth in macropropagated plantlets. The significant increase in bunch weight can be correlated with increased leaf area during the cropping period which accelerated the process of photosynthesis and carbohydrate formation. The relatively higher accumulation of carbohydrates in the leaves could promote growth rate and in turn increase the bunch yield (Manju and Pushpalatha, 2022). Finger length observed in the study was more in macropropagated plantlets than suckers in Grand Naine, Rasthali and Neypoovan. Quality characters like TSS and fruit acidity did not vary significantly between the two planting materials. Manju and Pushpalatha (2020) reported that macropropagated plantlets of Grand Naine and Nendran responded as good as tissue culture plants and significantly better than suckers in terms of bunch weight, hands bunch^{-1}, fingers bunch^{-1} and finger weight. Earlier works in plantain by Opata et al. (2020) also brought out

Table 5: Effect of planting material on growth characters of banana

Treatment	Plant height (cm)	Pseudostem girth (cm)	Leaves plant^{-1}	Suckers plant^{-1}	Leaf area (m^2)	Days to bunching	Days to maturity	Crop duration (days)
Nendran- M	283.00	52.80	10.85	5.80	10.67	188.80	89.40	310.40
Nendran- S	277.00	52.40	9.90	6.00	9.63	194.60	94.00	292.60
SEm±	6.56	0.57	0.04	0.35	0.25	4.33	2.43	4.64
CD (p=0.05)	NS	NS	0.14	NS	0.99	NS	NS	NS
Kadali-M	238.00	41.80	9.60	3.40	10.82	198.80	86.40	284.80
Kadali- S	231.20	41.80	8.60	4.00	9.61	197.80	87.40	285.20
SEm±	3.34	1.03	0.22	0.36	0.27	5.80	1.91	6.41
CD (p=0.05)	NS	NS	0.90	NS	1.08	NS	NS	NS
Rasthali-M	306.00	53.10	9.48	4.00	14.86	287.00	91.00	378.00
Rasthali- S	308.00	52.30	8.60	3.89	13.35	289.20	87.80	377.00
SEm±	5.55	0.51	0.17	0.33	0.32	3.10	5.09	2.15
CD (p=0.05)	NS	NS	0.67	NS	1.30	NS	NS	NS
Neypoovan- M	313.80	53.37	11.05	7.40	11.83	229.20	110.00	339.20
Neypoovan- S	296.40	51.27	10.10	7.00	10.81	227.80	114.20	342.60
SEm±	2.42	0.35	0.23	0.28	0.18	2.80	3.01	3.18
CD (p=0.05)	9.74	1.41	0.94	NS	0.71	NS	NS	NS
Poovan- M	290.00	53.90	11.40	4.00	17.08	203.20	119.00	322.80
Poovan- S	260.00	51.80	10.40	4.20	15.31	200.00	126.60	326.60
SEm±	3.16	0.62	0.22	0.35	0.33	4.85	2.95	3.35
CD (p=0.05)	12.75	NS	0.90	NS	1.31	NS	NS	NS
Grand Naine- M	220.80	50.60	10.40	4.000	15.094	201.60	116.80	318.40
Grand naine- S	221.00	54.00	9.40	4.01	13.20	199.40	117.60	316.20
SEm±	2.93	1.04	0.22	0.32	0.13	3.33	3.87	2.75
CD (p=0.05)	NS	NS	0.90	NS	0.51	NS	NS	NS

M: Macropropagated plantlet; S: Sucker

Table 6: Effect of planting material on bunch, finger and quality characters of banana

Treatment	Bunch weight (kg plant^{-1})	Hands bunch^{-1}	Fingers bunch^{-1}	Finger weight (g)	Finger length (cm)	Finger girth (cm)	TSS (°B)	Fruit acidity (%)
Nendran- M	21.70	9.60	229.60	131.60	17.86	11.86	20.70	0.23
Nendran- S	16.60	8.40	149.20	118.20	17.04	11.10	20.08	0.22
SEm±	0.67	0.27	5.82	1.51	0.17	0.19	0.56	0.01
CD (p=0.05)	2.69	1.07	23.47	6.09	0.68	0.77	NS	NS
Kadali-M	7.10	7.40	118.20	86.60	13.80	8.62	26.20	0.19
Kadali- S	5.74	5.60	77.80	77.40	12.74	8.02	26.86	0.19
SEm±	0.20	0.14	3.61	1.81	0.38	0.15	0.34	0.01
CD (p=0.05)	0.81	0.57	14.55	7.29	NS	0.51	NS	NS

Table 6: continue...

Treatment	Bunch weight (kg plant^{-1})	Hands bunch^{-1}	Fingers bunch^{-1}	Finger weight (g)	Finger length (cm)	Finger girth (cm)	TSS (°B)	Fruit acidity (%)
Rasthali-M	16.00	8.20	110.00	113.60	17.52	12.30	28.20	0.34
Rasthali- S	9.00	6.60	75.40	88.40	15.60	11.08	28.46	0.33
SEm±	0.25	0.36	5.23	5.81	0.14	0.27	0.40	0.01
CD (*p*=0.05)	1.02	1.45	21.08	23.41	0.55	1.10	NS	NS
Neypoovan- M	16.88	9.80	166.20	99.80	17.34	13.10	22.90	0.27
Neypoovan- S	14.50	8.60	125.20	91.80	16.68	12.34	23.14	0.25
SEm±	0.39	0.27	6.91	1.29	0.22	0.05	0.17	0.01
CD (*p*=0.05)	1.56	1.07	27.86	5.18	NS	0.21	NS	NS
Poovan- M	13.10	6.50	67.40	189.80	22.20	12.68	25.60	0.27
Poovan- S	10.32	5.30	57.20	174.40	20.82	12.06	26.00	0.28
SEm±	0.28	0.27	1.17	2.31	0.74	0.13	0.28	0.01
CD (*p*=0.05)	1.14	1.07	4.72	9.31	NS	0.51	NS	NS
Grand Naine- M	15.00	11.67	183.20	79.20	14.04	11.98	24.20	0.30
Grand naine- S	13.50	10.70	166.60	69.60	13.20	11.34	24.34	0.28
SEm±	0.28	0.12	2.80	1.04	0.16	0.07	0.07	0.01
CD (*p*=0.05)	1.12	0.46	11.28	4.19	0.65	0.29	NS	NS

M: Macropropagated plantlet; S: Sucker

the superior performance of macropropagated plantlets than suckers with respect to bunch weight.

4. CONCLUSION

The present investigation confirmed varietal variability for their response to media under macropropagation. Among the varieties, nendran was the most responsive with sawdust media. The study presented the possibility of macropropagation technology as a means to address the shortage of quality planting material in banana. Further, the suitability of macropropagated plantlets as a quality planting material of banana was ascertained based on their field performance by which farmers can ensure better returns and sustain farming even under accidental crop loss.

5. FURTHER RESEARCH

This study recommends that the following knowledge gaps be considered in the future. Effects of corm circumference, altitude and prevailing weather conditions, particle size of media, method of hormone application on plantlet production need investigation for further refinement of technology. The authors would like to thank Government of Kerala (Annual State Plan) for the financial support in conducting the investigation.

6. REFERENCES

Adegoke, K.A., Adesina, O.O., Okon-Akan, O.A., Adegoke, O.R., Olabintan, A.B., Ajala, O.A., Olagoke, H., Maxakato, N.W., Bello, O.S., 2022. Sawdust-biomass based materials for sequestration of organic and inorganic pollutants and potential for engineering applications. Current Research in Green and Sustainable Chemistry 5, 100274. DOI https://doi.org/10.1016/j.crgsc.2022.100274.

Anonymous, 2013. Good agricultural practices for greenhouse vegetable crops - Principles for Mediterranean climate areas. Plant Production and Protection paper 217, FAO, Rome, Italy, 271–302.

Anonymous, 2016. Package of Practices Recommendations: Crops 2016 (14thEdn.). Kerala Agricultural University Press, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala, 360.

Anonymous, 2021. Farm Guide 2021. Farm Information Bureau, Agriculture Development and Farmer's Welfare Department, Government of Kerala, 272. Available at https://www.fibkerala.gov.in/sites/default/files/ inline-files/Farmguide%202021.pdf. Accessed on 31st Jan, 2022.

Archith, T.C., Devappa, V., Mesta, R.K., Honnabyraiah, M.K., Rudresh, D.L., 2021. Survey on panama wilt disease (*Fusarium oxysporum* f.sp. *cubense*) of banana in Mysuru, Mandya and Chamarajanagar districts of Karnataka. International Journal of Economic Plants 8(1), 73–80.

Arenas, M., Vavrina, C.S., Cornell, J.A., Hanlon, E.A., Hochmuth, G.J., 2002. Coir as an alternative to peat in media for tomato transplant production. HortScience 73, 309–312.

Barker, W.G., Steward, F.C., 1962. Growth and development of banana plant: I. The growing regions of the vegetative shoot. Annals of Botany 26(3), 389–411.

Bhende, S.S., Kurien, S., 2015. Sucker production in banana. Journal of Tropical Agriculture 53(2), 97–106.

Bohra, P., Waman, A.A., Sathyanarayana, B.N., Umesha, K., 2013. Preliminary assessment of intra-clonal variability in Indian banana varieties for sucker production. Indian Journal of Natural Products and Resources 4(4), 387–391.

Dayarani, M., Dhanarajan, M.S., Uma, S., Durai, P., 2013. Macropropagation for regeneration of wild bananas (*Musa* spp.). Advanced BioTech 12(12), 16–18.

Di Lorenzo, R., Pisciotta, A., Santamaria, P., Scariot V., 2013. From soil to soilless in horticulture: Quality and typicity. Italian Journal of Agronomy8(4), 255–260.

Dzomeku, B.M., Darkey, S.K., Wünsche, J.N., Bam, R.K., 2014. Response of selected local plantain cultivars to PIBS (Plants issus de Bourgeons secondaires). Journal of Plant Development 21, 117–123.

Ede, A.E., Ndubuaku, U.M., Baiyeri, K.P., 2015. Media effects on emergence and growth of moringa (*Moringa oleifera* Lam) seedlings in the nursery. American Journal of Experimental Agriculture7(3), 182–189.

Hussein, N. 2012. Effects of nutrient media constituents on growth and development of banana (*Musa* spp.) shoot tips cultured *in vitro*. African Journal of Biotechnology 11, 9001–9006.

Iqbal, N., Umar, S., Khan, N.A., Khan, M.I.R., 2014. A new perspective of phytohormones in salinity tolerance: Regulation of proline metabolism. Environmental and Experimental Botany 100, 34–42.

Jung, J.Y., Ha, S.Y., Yang, J.K., 2017. Steam treated sawdust as soil less growing media for germination and growth of horticulture plant. Journal of Korean Wood Science and Technology 45(6), 857–871.

Kindimba, G.V., Msogoya, T.J. 2014. Effect of benzylaminopurine on in vivo multiplication of french plantain (*Musa* spp., AAB) cv. 'Itokesege'. Journal of Applied Biosciences 74(1), 6086–6090. DOI: https://doi.org/10.4314/ jab.v74i1.1

Kwa, M. 2003. Activation de bourgeons latents et utilisation de fragments de tige du bananier pour la propagation en masse de plants en conditions horticoles in vivo. Fruits 58(06), 315 – 328. DOI: 10.1051/fruits:2003018

Manju, P.R., Pushpalatha, P.B., 2020. Macropropagated plantlets in banana: Performance evaluation with suckers and tissue culture plants in Grand Naine and Nendran. Journal of Tropical Agriculture 58(2), 263–268.

Manju, P.R., Pushpalatha, P.B., 2022. Effect of organic nutrients on the yield and quality of banana cv. Nendran (*Musa* spp., AAB). International Journal of Bio-resource and Stress Management 13(2), 179–186.

Mariyappillai, A, Arumugam, G., 2021. Physico-chemical and hydrological properties of soil less substrates. Journal of Environmental Biology 42, 700–704.

Menon, R., Nair, S., Suma, A., Manju, P. R., Cherian, A. K., Patil P., Agrawal, A., 2014. Introduction, evaluation and adoption of an exotic banana (*Musa* AAB cv. 'Popoulu') (EC 320555) to Kerala. Indian Journal of Plant Genetic Resources 27(3), 298–302.

Munns, R., Tester, M., 2008. Mechanisms of salinity tolerance. Annual Review of Plant Biology 59, 651–681.

Murray, D.B., 1960. The effect of deficiencies of major nutrients on growth and leaf analysis of the banana. Tropical Agriculture Trinidad and Tobago 37, 97–106.

Njukwe, E., Ouma, E., van Asten, P.J.A., Muchunguzi, P., Amah, D., 2013. Challenges and opportunities for macropropagation technology for *Musa* spp. among small holder farmers and small and medium scale enterprises. In: Blomme, G., van Asten, P.J.A., Vanlauwe, B. (Eds.). Banana Systems in the Humid Highlands of Sub-Saharan Africa. CABI publishing, 66–71.

Ntamwira, J., Sivirihauma, C., Ocimati, W., Bumba, M., Vutseme, L., Kamira, M., Blomme, G., 2017. Macropropagation of banana/plantain using selected local materials: A cost-effective way of mass propagation of planting materials for resource-poor households. European Journal of Horticultural Sciences 82(1), 38–53.

Opata, J., Skala, J., Hegele, M., Dzomeku, B.M., Wünsche, J.N., 2020. Macropropagation of banana (*Musa* AAA): Responses to hormonal and mechanical corm manipulation. Fruits 75(2), 78–83.

Panse, V.G., Sukhatme, P. V., 1967. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi, 347.

Park, E.Y., Choi, J.M., Shim, C.Y., 2014. Development of root media containing carbonized and expanded rice hull for container cultivation of horticultural crops. Journal of the Korean Society for Horticultural Science 32, 157–164.

Patil, P., Naduthodi, N., Sujatha, S., 2016. Proceedings of the 3rd Group Discussion of ICAR - All India Coordinated Research Project on Fruits -Tech. Doc. No. 118. ICAR – Indian Institute of Horticultural

Research, Bengaluru, 263.
Pavitra, K., Rekha, A., Ravishankar, K.V., 2017. Adoption of macropropagation technique for multiplication of unique banana hybrids to enhance number of propagules. Vegetos – An International Journal of Plant Research and Biotechnology 30(2), 274–279.
Phukan, P.T., Baruah, K., Bhattacharyya, R.K., 2016. Effect of organic nutrient schedule on growth, yield and quality of banana cv. Jahaji (AAA). Environment and Ecology 34(4D), 2458–2461.
Rajenimbalkar, V.M., Shaikh, N.B., Badgujar, C.D. 2021. Effect of biofertilizers on macropropagation of banana. International Journal of Farm Sciences 11(1&2), 61–65.
Ranganna, S., 1986. Manual of Analysis of Fruit and Vegetable Products (3rd Edn.). Tata McGraw Hill Publishing Company Ltd., New Delhi, 1112.
Sadom, L., Tomekpe, K., Folliot, M., Cote, F.X., 2010. Comparison of the effectiveness of two vegetative propagation methods for banana trees from the study of the agronomic characteristics of a hybrid of plantain (*Musa* spp.). Fruits 65(1), 3–9.
Sajith, K.P., Uma, S., Saraswathi, M.S., Backiyarani, S., Durai, P., 2014. Macropropagation of banana - Effect of bio-fertilizers and plant hormones. Indian Journal of Horticulture 71(3), 299–305.
Santana, E.B., Coelho, E.F., Goncalves, A.S., Cruz, J.L., 2020. Physiological and vegetative behaviour of banana cultivars under irrigation water salinity. RevistaBrasileira de EngenhariaAgricola e Ambiental 24(2), 82–88.
Singh, S., Dubey, R.K., Kukal, S.S., 2015. Performance of cocopeat amended media mixtures on growth and flowering of chrysanthemum. Journal of Applied Horticulture 17(3), 230–235.
Subbaraj, A.K., 2011. Topolins: Current research status and applications. International Journal of Bio-resource and Stress Management. 11(1), 10–25.
Taulya, G., van Asten, P.J.A., Leffelaar, P.A., Giller, K.E., 2014. Phenological development of East African highland banana involves trade-offs between physiological age and chronological age. European Journal of Agronomy 60, 41–53.
Thiemele, D.E.F., Issali, A.E., Traore, S., Kouassi, K.M., Aby, N., Gnonhouri, P.G., Kobenan, J.K., Yao, T.N., Adiko, A., Zakra, A.N. 2015. Macropropagation of plantain (*Musa* spp.) cultivars Pita 3, FHIA 21, Orishele and Corne 1: Effect of benzylaminopurine (BAP) concentration. Journal of Plant Development 22, 31–39.
Tumuhimbise, R., Talengera, D., 2018. Improved propagation techniques to enhance the productivity of banana (*Musa* spp.). Open Agriculture 3, 138–145.