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Physical and Mechanical Properties of Tissue Culture Banana Plantlets for the Design of Planting Mechanism

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Authors' contributions

This work was carried out in collaboration among all authors. Author BHP conducted the study at the laboratory and prepared the manuscript. Authors SSS and JJG advised and gave necessary technical support throughout the study and disciplined the manuscript. Authors AS and VAA are part of advisory committee and provided necessary technical support and suggestions for this study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To design a mechanical transplanting mechanism for tissue culture banana plantlets, physical and mechanical properties such as mass, height of plantlet, pseudostem height from tray to first leaf, pseudostem diameter between root plug and first leaf, root plug dimension, moisture content of root plug, pulling force and compression resistance are needed.
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Methodology: For three local varieties used by the farmers to culivate tissue culture banana namely 'Grand Naine-G9' (AAA), 'Red Banana' (AAA) and 'Nendran' (BAA), physical and mechanical properties were studied.
Results: 'G9', 'Red Banana' and 'Nendran' were 120.5±12.3, 117.2± 9.0 and 113.5±9.0 g mass and 379.3±21.72, 360±26.23, 467.6±13.06 mm height, pseudostem diameter near root plug was observed as 10.7 ± 1.0, 10.2 ± 0.8 and 10.9 ± 1.4 mm respectively. The height of pseudostem till the first leaf was minimum for 'Red' variety (37.1±4.3 mm), maximum for 'Nendran' (102.1±2.3 mm). The pulling force for three varieties were observed as 4.96±2, 4.97±1.1 and 5.05±1.6 N with little difference in-between them. The minimum compressive resistance offered by the three varieties are 47.16 ± 3.08, 46.42 ± 5.43 and 38.55 ± 1.86 N near the base and 44.07 ± 2.55, 37.89 ± 6.6 and 32.36 ± 1.58 N at 25 mm above root plug for 'G9', 'Red' and 'Nendran' respectively.
Conclusion: The maximum plantlet weight was observed as 132.8 mm for 'G9' variety and plantlet height as 480 mm for 'Nendran' variety. The minimum height of pseudostem till the first leaf was 31 mm for 'Red' variety and picking gripper height should be less than 30 mm. The minimum pulling force should be 7 N to remove the plantlet from the pro-tray and force applied by the gripper to hold the plantlet on pseudostem shouldn't exceed 30 N.

Keywords: Banana planter; pseudostem diameter; pseudostem height; compressive resistance; gripping force; pulling force.

1. INTRODUCTION

Banana (Musa *sp*.) is one of the important horticultural crops, which yield almost year round in India. It is conventionally propagated using the suckers which are produced from the auxiliary buds of rhizomes or corms as a starting material. The tissue culture banana plantlets provide disease free material and pest infestations. When comparing micro-propagated with conventional planting material (i.e. suckers), micro-propagated banana were capable of performing equally or better in terms of mean plant height, time to bunch emergence, time to harvest, average bunch weight, average number of fingers as well as weight per bunch and hands per bunch for most of the varieties [1,2,3]. Wong et al. (2017) studied the nursery technique for banana plantlets and reported that height and girth parameters (pseudostem diameter) are some of the important physical properties for successful planting of tissue culture banana [4]. Even though studies conducted under tissue culture banana plantlets for quality of planting material as well its yield, no physical properties study was conducted for mechanical planting. In order to design planting mechanism for mechanized planting, it is necessary to obtain the physical and mechanical properties. Mao et al. (2014) studied plant height, root lump dimensions and weight of plug seedling for development of pincette-type pick-up device for automatic transplanting of cauliflower seedlings in greenhouse [5]. Sivakumar and Durairaj (2014) studied agronomical parameters like plant height, stem diameter, number of leaves and root weight to find any influence of the media on the growth of seedlings when grown in open bottom type pro-tray and reported that no significant difference existed between them [6]. Jiaodi et al. [7] studied variety, seedling average height and moisture content of root plug for development of picking mechanism for tomato seedlings.

The pseudostem is the important part of the plantlet. The part inside the pseudostem is called as aerial stem which grows into cigar leaf, should not be damaged during the planting. The compressive strength helps to fix the gripper force preventing damage to the stem which affects its mortality during the initial establishment in the field. Han et al. (2013) studied compression resistance at root clump moisture content of 54.21 per cent to 60.47 per cent for 28 days old seedlings using texture analyzer (TA-XT2i model) [8]. Pandirwar et al. [9] studied mass of seedling, moisture content of plant, bulb and collar diameter, height of seedling and compressive strength for design of planter for three varieties of onion seedlings. To remove the plantlet from pro-tray, pulling force is applied. Vivek et al. [10] studied stem diameter, shoot length, root length, number of leaves and pulling force for tomato, brinjal and chilli to develop gripping type transplanting mechanism. Jin et al. [11] studied size of tray holding the seedlings, moisture content of root plug, height, stem diameter, mass, compressive resistance for tomato seedlings to develop automatic transplanting mechanism for vegetable seedlings.

2. MATERIALS AND METHODS

The experiment was carried out using commercially available matured tissue culture banana plantlets of three varieties namely 'Grand Naine (G9)' (AAA), 'Red Banana' (AAA) and 'Nendran' (BAA) with 48 replications (Fig. 1). Tissue culture G9 variety is more famous for its commercial value, 'Red Banana' is cultivated in hilly areas and 'Nendran' variety of banana is widely distributed and have high market demand in Tamil Nadu. The observations were taken for plantlet mass, height of plantlet, height of pseudostem from tray to first leaf, pseudostem diameter, root plug dimension, moisture content of root plug, pulling force and compression resistance of the pseudostem (Fig. 2).

The banana plantlets were weighed using electronic weighing balance with a least count of 0.1 g (Fig. 2a). The height of plantlet was measured through longest dimension when the plantlets were kept in tray from tray bottom level to the tip of top leaf with the help of 1 m steel scale with a least count of 1 mm. The height of first leaf sheath from the root plug was measured using vernier caliper with a least count of 0.01 mm (Fig. 2b). The diameter of pseudostem for banana plantlets at three levels namely, near the root plug, node just below the first leaf sheath and in-between these two (25 mm above the root plug) were measured using vernier caliper. The root plug dimension was measured using 150 mm steel rule having a least count of 0.5 mm [6]. The moisture content of root plug was determined by gravimetric method [6,7,11]. The soil sample from root plug of known weight was placed in hot air oven at 105°C for 24 hours and weighed every 6 hours interval.

The pulling force required to remove the plantlet from the tray was measured using a Lutron FG-5000A force gauge having a resolution up to 0.05 N [10]. The force gauge was fixed on a frame, which can be moved up and down by rotating the handle (Fig. 2c). The plantlet in erect position was connected to force gauge in straight line and the pulling force was observed directly from the indicator while pulling the plantlet outside the tray.

The compressive resistance was measured using Stable Microsystems TA-HD Plus texture analyser with a 500 N load cell and measurement resolution of 0.1 N [8,9,11]. The plantlet was positioned on the specimen support (Fig. 2d) so that it was compressed at the location of pseudostem near root plug and 25 mm above the base. It was programmed to apply the force at the uniform rate just above the stem to the desired depth and the force required to achieve the compression was sensed and recorded in the texture analyser.

Fig. 1. Varieties used for measuring physical and mechanical properties of tissue culture plantlets of Banana a) Grand Naine (G9) b) Red Banana c) Nendran

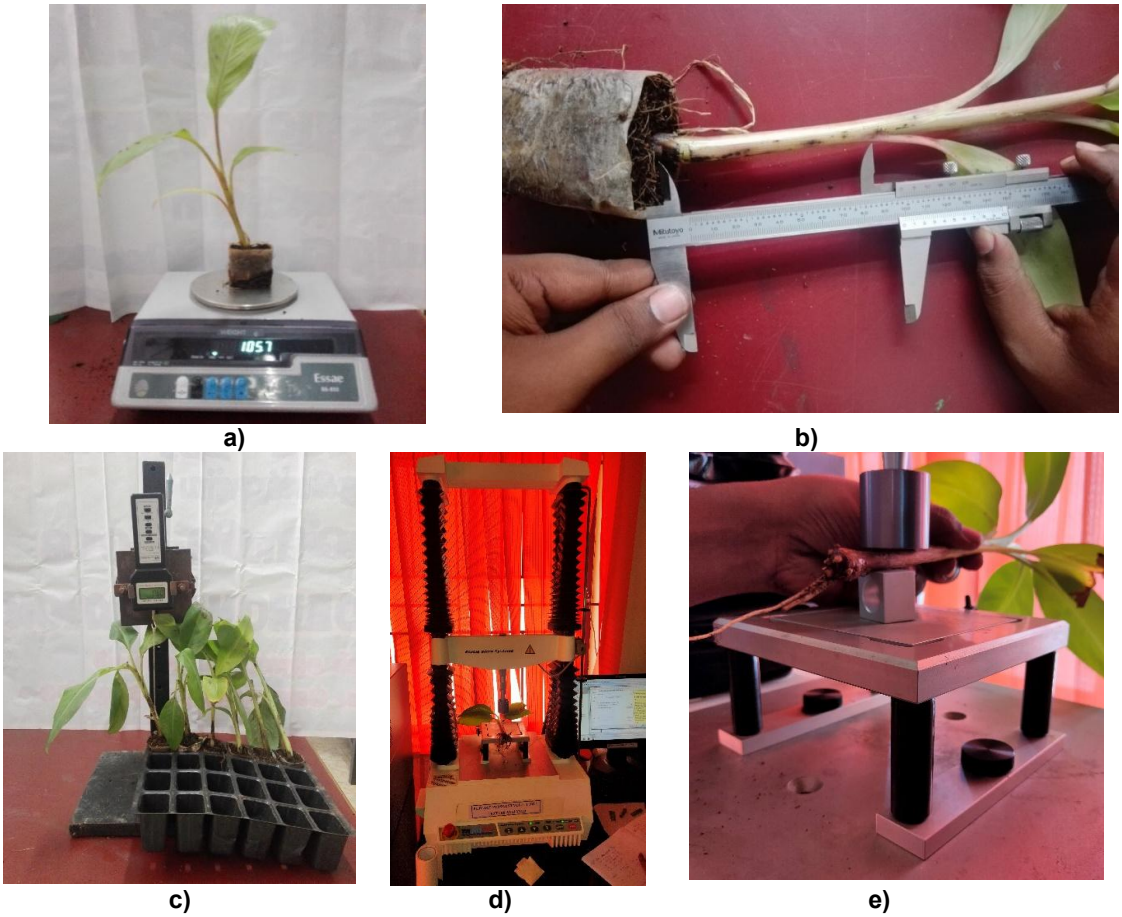

Fig. 2. Measurement of physical and mechanical properties of banana plantlets a) Mass of plantlet b) Height of first leaf from root plug c) Pulling force of banana plantlet d) Compressive resistance using texture analyser e) position of banana plantlet in texture analyser

3. RESULTS AND DISCUSSION

The important physical and mechanical parameters required for tissue culture banana plantlets to the design of planting mechanism are tabulated in the Table 1. Results show that three varieties 'G9', 'Red Banana' and 'Nendran' were 120.5±12.3, 117.2± 9.0 and 113.5±9.0 g mass and 379.3±21.7, 360±26.2, 467.6±13.0 mm height respectively. The mass of the plantlet varies with the variety even though the tray size 65 x 45 x 70 mm utilized for the growth of plantlet (root plug dimension) as well as age of the plantlet were same. The height of the plantlet also varies with the variety with 'Red Banana' being the smallest and 'Nendran' being the tallest among the three. This is due to the fact that 'Red Banana' variety takes 16-18 months for full maturity whereas 'G9' variety takes 11-12 months and 'Nendran' takes 10-11 months.

The pseudo stem diameter near root plug for 'G9', 'Red Banana' and 'Nendran' was observed as 10.8 ± 1.0, 10.2 ± 0.8 and 10.9 ± 1.4 mm respectively. The pseudo stem diameter near first leaf and 25 mm above root plug was observed to be same and reported as 9.1 ± 0.6, 9.5 ± 0.6 and 8.8 ± 0.9 mm for three varieties respectively. The pseudo stem diameter decreases for all the varieties when moved to top from root plug position. 'Red Banana' variety was observed to be smaller diameter at the base whereas reduction in diameter was minimum among the three. The growth of 'Red Banana' variety takes more time resulting in smaller diameter and lowest value among three. The height of pseudostem till the first leaf was minimum for 'Red Banana' (37.1 ± 4.3 mm), maximum for 'Nendran' (102.1 ± 2.3 mm) and in between for 'G9' (78 ± 16.7 mm). This is also due to variation in growth period among the three varieties.

Table 1. Physical and mechanical properties of selected banana plantlet varieties

Parameter	Variety		
	G9	Red Banana	Nendran
Mass of plantlet (g)	120.47 ± 12.27	117.20 ± 9.08	113.50 ± 9.08
Height of plantlet (mm)	379.3 ± 21.72	360.0 ± 26.23	467.6 ± 13.06
Pseudostem diameter (mm)			
i) near root plug	10.75 ± 1.02	10.24 ± 0.85	10.89 ± 1.38
ii) near first leaf	9.13 ± 0.63	9.52 ± 0.65	8.8 ± 0.89
iii) in-between	9.13 ± 0.63	9.52 ± 0.65	8.8 ± 0.89
Height of pseudostem up to first leaf (mm)	78.0 ± 16.70	37.1 ± 4.33	102.1 ± 2.33
Root plug dimension (mm)	60 x 45 x 70	60 x 45 x 70	60 x 45 x 70
Moisture content of root plug (%)	12 ± 2.8	12 ± 3	12 ± 3
Pulling force (N)	4.96 ± 2	4.97 ± 1.11	5.05 ± 1.58
Compressive resistance			
i) minimum resistance at stem near root plug (N)	47.16 ± 3.08	46.42 ± 5.43	38.55 ± 1.86
ii) maximum resistance at stem near root plug (N)	137.9 ± 30.07	67.42 ± 6.28	108.76 ± 10.7
iii) minimum resistance at stem 25mm above root plug (N)	44.07 ± 2.55	37.89 ± 6.6	32.36 ± 1.58
iv) maximum resistance at stem 25mm above root plug (N)	99.49 ± 8.75	64.31 ± 4.13	84.64 ± 3.78

The variation in moisture content of root plug was observed to minimum. A biodegradable cover was provided around the root plug which nullifies the effect of moisture content on other properties. The pulling force necessary to pull the plantlet from tray was observed to be same for all the varieties and a minimum variation was observed which may be caused by the effect of variation in mass of the plantlet.

Minimum compressive resistance which doesn't damage the aerial stem and the force resulting in complete damage was observed. For 'G9' and 'Nendran' varieties, reducing the diameter of pseudostem by 3 mm doesn't affect the aerial stem whereas for 'Red Banana' it was 2 mm. This was due to the lower diameter comparing other two varieties. Reducing the diameter by 5 mm for both 'G9' and 'Nendran' varieties resulting in complete damage of aerial stem whereas for 'Red Banana' reducing the diameter by 4 mm resulting in aerial stem damage. The minimum compressive resistance offered by the three varieties are 47.16 ± 3.08, 46.42 ± 5.43 and 38.55 ± 1.86 N near the base and 44.07 ± 2.55, 37.89 ± 6.6 and 32.36 ± 1.58 N at 25 mm above base for 'G9', 'Red Banana' and 'Nendran' respectively. The force resulted in damage of aerial stem was observed as 137.9 ± 30.07, 67.42 ± 6.28 and 108.76 ± 10.7 N near base and 99.49 ± 8.75, 64.31 ± 4.13 and 84.64 ± 3.78 N at 25 mm above the base for 'G9', 'Red Banana' and 'Nendran' respectively.

4. CONCLUSION

To design a planter, for calculation of mass handled, the maximum mass of the plantlet is considered. The maximum plantlet mass was observed as 132.8 g for 'G9' variety. The plantlet height is required in many places such as deciding the feeding tube height of planter and the maximum height was observed as 480 mm for 'Nendran' variety. To design the gripper, plantlet diameter and pseudostem height between root plug and first leaf was necessary and it can be fixed based on the variety being handled. The maximum pulling force to remove the plantlet from the tray was observed as 7 (6.96) N and a minimum of this force should be applied to remove the plantlets from pro-tray. The force required by the gripper to hold the plant shouldn't exceed minimum compressive resistance and should be below 30 N otherwise it may result in damage of aerial stem.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hanumantharaya MR, Kerutagi MG, Patil BL, VC K, Bankar B. Comparative economic analysis of tissue culture banana and sucker propagated banana production in Karnataka. Karnataka J. Agric. Sci. 2009;22(4):810–815.
2. Karthick V, Mani K. Comparative economic analysis of tissue culture banana and sucker propagated banana production under precision farming technology in Tamil Nadu. Madras Agricultural Journal. 2013;100.
3. Patil YJ, Patil VS. Effect of planting material and mode of fertilizer application on growth, yield and soil properties of banana under Western Ghat Zone. Vegetos- An International Journal of Plant Research. 2017;30(1): 64–68.
4. Wong KF, Suhaimi O, Fatimah K. On-farm grower-friendly nursery technique for acclimatization of tissue-cultured banana seedlings. Asian Journal for Poverty Studies. 2017;3(2):146–151.
5. Mao H, Han L, Hu J, Kumi F. Development of a pincette-type pick-up device for automatic transplanting of greenhouse seedlings. Applied Engineering in Agriculture. 2014;30(4):547–556. Available:https://doi.org/10.13031/aea.30.10550
6. Sivakumar S, Durairaj CD. Development of a gravity fed automatic vegetable transplanter. Trends in Biosciences. 2014; 7(3):407–410.
7. Jiaodi L, Weibin C, Dongyang T, Haiyang T, Hongzheng Z. Kinematic analysis and experiment of planetary five-bar planting mechanism for zero-speed transplanting on mulch film. International Journal of Agricultural and Biological Engineering. 2016;9(4):84–91. Available:https://doi.org/10.3965/j.ijabe.20160904.2073
8. Han L, Mao H, Hu J, Mao X, Kunpeng T, Xuejun Y. Experiment on mechanical property of seedling pot for automatic transplanter. Transactions of the Chinese Society of Agricultural Engineering. 2013; 29(2):24–29.
9. Pandirwar A, Kumar A, Mani I, Islam S. Biometric properties of onion seedlings relevant to the development of onion seedling transplanter. Journal of Applied and Natural Science. 2015;7(2):768–773. Available:https://doi.org/10.31018/jans.v7i2.681
10. Vivek P, Duraisamy VM, Kavitha R. Development of an automatic transplanting mechanism for protray vegetable seedlings. Madras Agricultural Journal. 2017;104(10–12):401–404. Available:https://doi.org/10.29321/maj.2017.000087
11. Jin X, Li D, Ma H, Ji J, Zhao K, Pang J. Development of single row automatic transplanting device for potted vegetable seedlings. International Journal of Agricultural and Biological Engineering. 2018;11(3):67–75. Available:https://doi.org/10.25165/j.ijabe.20181103.3969

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