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Design and development of power-operated continuous-run potting machine for seedling-nursery

M MUTHAMIL SELVAN[1], C K THANKAMANI[2], S J K ANNAMALAI[3] and E JAYASHREE[4]

Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

Potting is still a manual operation in plantation, forestry, and 11 other horticultural nurseries in India and the preparation of pot-mixture and filling in polybags are crucial tasks and are time consuming. Therefore, a power-operated continuous-run machine was specially designed, fabricated, and tested to master seedling-nursery management capable of mixing, pulverizing, sieving, and filling of pot ingredients in polybags. The machine is a vertical free-standing unit mounted on four legs and consists of 3-hp motor, feed-hopper, pulverizing chamber with 8-numbers of paddles, sieving compartment operated by a slider-crank mechanism, vending instrumentation, and outlet. Ingredients like soil, sand, granite power, farmyard manure, and compost are fed from the top and the pot-mixture is collected at the bottom. Electronic vending is the novelty of the machine, which permits filling pot-mixture at set quantity at set time-gap. Aggregate analysis, degree of pulverization, and other physical parameters of machine-made mixture are at recommended level as well as on par with manually-made pot-mixture. More proportion (81.8%) of desirable level of aggregate was achieved with machine compared in manual method (79.5%) resulted in improved quality of the mixture for seedling establishment. Bagging through machine worked out 71.4% cost-saving and 80.2% time-saving. The machine is recommended for nursery-holders around the nation since the machine can provide pot-mixture for development of saplings of 30 000 numbers per month in a commercial nursery.

Key words: Bagging machine, Potting machine, Potting media, Propagating medium

The production of seedlings of ornamental, horticultural and forestry in polybags is a major enterprise in the country. Quality planting material is the foremost important factor in the successful field establishment. Preparation of pot-mixture and filling the pot-mixture in seedling-bags uniformly is a crucial task in nursery management. Moreover all the commercial models available are suitable for pots only and not for poly bags. Keeping the facts in view, a pot machine for preparation and filling of pot-mixture in nursery bags uniformly.

Media for plant growth and seed germination has great significance in nursery business. Propagating medium plays an important role in raising of successful plant material in nursery production. Propagating medium is the substance, be it peat, sand, cocopeat, vermiculite or other material, into which the unrooted cuttings are inserted or seeds are sown for germination (Cáceres 2014, Run-Hua *et al.* 2012, Essegbemon *et al.* 2014a). The material for rooting and growing media may be used either alone or incorporated with one or more products in combination. The materials used for rooting media may be naturally occurring or max; be manufactured artificially. In many cases, the waste or surplus products from the industries, viz. saw dust is used for this purpose (Elsayed and Mahrouk 2010, Resham 2012).

Traditionally pot media is mixed and filled in poly bags in manual method only. The pot media are being mixed by spade preferably by men laborers. Then women workers are filling the pot-mixture in poly bags in sitting posture. It seems there is no machine is used for mixing and filling the pot-mixture in poly bags in the country. There is no literature found on the mechanization of pot in Indian horticultural farms. In the existing method of media preparation in the horticultural nurseries, both men and women labourers are essentially required for mixing and filling the media respectively. It is not only a tedious job with poor output, but also a laborious work. It also costs more for completing the task in time. In manual method, only 300-350 bags of 500 g can be filled in a day which costs ₹ 1 140 per 1 000 bags (Kasten 2011, Essegbemon *et al.* 2014b). The present operation, which is carried out manually using spade for mixing, pulverizing, is usually done in unscientific manner and there is no control to

[1]Senior Scientist (e mail: m_muthamil@yahoo.co.in), Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi 110 012; [2]Principal Scientist (e mail: thankamani@spice.res.in), [4]Senior Scientist (e mail: ejayasree05@yahoo.com), Indian Institute of Spices Research, Calicut, Kerala 673 012; [3]Principal Scientist (e mail: sjackanna@gmail.com), Central Institute of Agricultural Engineering, Regional Centre, Coimbatore, Tamil Nadu 641 003

avoid contamination in manual handling. Moreover, it is tedious in the bending posture during the operation with spade.

By considering the prevailing scenario of pot media preparation and handling, a power-operated continuous run potting machine was designed and developed at Central Institute of Agricultural Engineering, Regional Centre, Coimbatore, India. The paper deals with the design criteria, agronomical requirement of pot media handling, fabrication of the prototype, and performance evaluation including study of effect of machine potting in germination of the seedlings.

MATERIALS AND METHODS

This power operated continuous type pot machine is capable of mixing, pulverizing, sieving, and filling of pot ingredients in polybags at desired quantity. The unit consists of 3 hp motor, feed hopper, paddles, sieving tray, and electronic vending instrumentation. For spices nursery, the optimized ratio of soil, granite powder, and compost is 2:1:1 (v/v) is used for pot-mixture. Electronic vending is the novel approach adopted in this machine, which is used for filling the pot-mixture at set quantity (250, 500, 1000g, etc.) at set time gap with 90% accuracy which is the acceptable level in nursery practices. The uniformity of mixing, aggregate analysis, degree of pulverization, and other related parameters of machine made pot-mixture were at recommended level as well as on par with manually made pot-mixture. This gender friendly machine is of very aesthetic and compact design, portable and handy to transport to the gardens and fields. Any unskilled person can operate the machine. Two operators are required, and both the operators can safely and comfortably work with the machine in standing and sitting position (Gavin *et al.* 2013). The machine is shown in Fig 1.

The potting machine operation consisted of various unit operations, viz mixing cum pulverizing, sieving cum destoning, stirring, and vending. The mixing cum pulverizing of pot media fed through feed-hopper was carried out by eight numbers of paddles attached at central shaft revolving at 350 rpm. The central shaft was actuated by a 2.25 kW electric motor (3-phased) through speed reduction gears (Mangwandi *et al.* 2010). The feeding throat controls the smooth flow of the feed. The sieving cum destining is actuated through slider-crank mechanism (Volkan *et al.* 2014, Ali *et al.* 2012, Ming-Shyan *et al.* 2010, Rong-Fong *et al.* 2009). String is carried out for proper flow of end product without getting chocked in the delivery chute. The stirring mechanism is driven from the prime mover. Vending is carried out through two modes, viz electronic vending and pedal vending (Feng-Cheng *et al.* 2011). The electronic vending is actuated from the control panel. The electronic vending was instrumented in such a way that the potting mixture is dispensed in the polybag to the desired set weight which is controlled by a load cell and set time gap (Sujin and Sang 2011, Yang and Evans 2007). Pedal vending unit was also provided to use it as alternative way in the field condition. This is actuated by the foot of the operator (Fig 1).

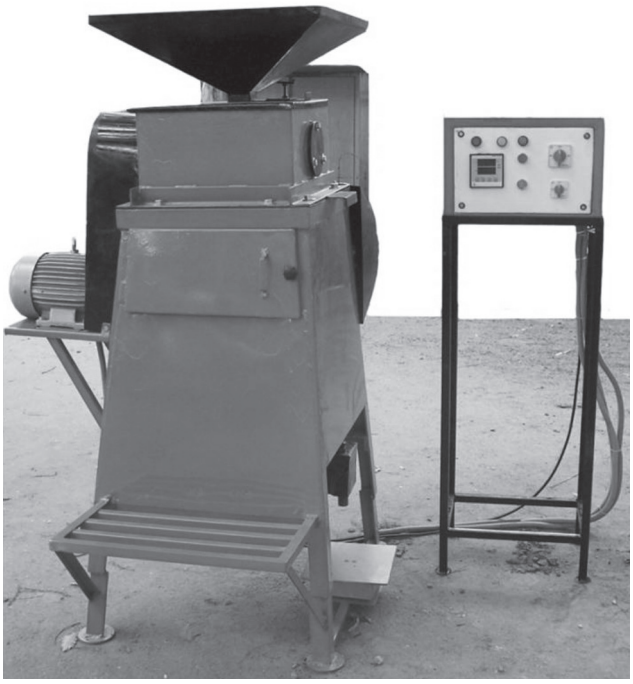

Fig 1 Prototype pot machine

Based on the materials used and labour requirement for the fabrication of the pot machine, the material cost and fabrication cost of the unit was calculated. The cost of operation per hour of the pot machine was worked out using the procedure recommended by RNAM test codes (Anon. 1995). This cost was compared with the cost of operation of the same by conventional method. The time and cost saved by using the pot machine against conventional method was compared.

RESULTS AND DISCUSSION

Optimization of agronomic parameters

The bulk density and moisture content of soil, sand, and farm yard manure were measured before and mixing. Fineness and tilth was determined through sieve analysis. Angle of repose of the mixture was also determined. The soil, granite powder, and FYM at the ratio of 2:1:1 (v/v) was adopted for the design of the machine.

Machine performance

The machine was evaluated in the laboratory condition and field condition at TNAU Botanic Gardens before installation at IISR farm. The observations on performance evaluation of pot machine are furnished in the tables.

Capacity of the machine

The working capacity of the machine was observed by taking different combinations. There is no significant difference on capacity of the machine with the combination of pot media as indicated in the Table and Fig 2.

Table 1 Performance of machine

Ratio of ingredients*	Weight of ingredients (kg)	Time taken (min)	No. of bags collected	Weight of bags (kg)	Capacity (kg/h)	Spillage	
						Bottom	Above sieve
2:1:1	200	54	261	126.3	140.3	5.9	12.5
	200	64	257	140.0	131.3	15.6	15.5
	200	57	270	126.8	133.5	7.7	13.2
2:0:1	200	70	259	129.5	111.2	7.6	7.6
	200	62	264	128.4	124.3	16.2	8.6
	200	57	234	134.2	141.3	12.4	12.9
2: 0.5 :1	200	51	219	129.4	152.3	13.4	11.7
	200	53	227	118.7	134.4	15.6	16.9
	200	58	237	128.6	133.0	14.7	16.4

*Soil:granite-powder:FYM, v/v

Table 2 Accuracy of potting

Weight set (g)	Machine				Traditional filling	
	Electronic vending		Pedal vending		Weight filled (g)	SD
	Weight filled (g)	SD	Weight filled (g)	SD		
250	243.18	20.1	260.4	26.4	275.1	28.7
500	514.60	37.2	519.2	40.9	479.7	44.6
750	741.92	64.7	769.7	86.4	785.4	93.5
1 000	1 032.9	82.0	1 076.2	93.5	967.3	105.6

Particle size distribution

The distribution of particle size determines the quality of the pot-mixture. The results on sieve analysis of both hand-made pot-mixture and machine made pot-mixture are furnished in Table and Fig. It is revealed from the observations of sieve analysis that the particle size distribution of both hand-made pot-mixture and machine made pot-mixture is on par. Hence the machine made pot-mixture is found to be most suitable for seedling establishment (Richards *et al.* 1986). It is also found that more proportion (81.8%) of desirable level of aggregate was achieved with machine made mixture compared in manual method (79.5).

The comparison of basic properties of pot-mixture prepared by manual method and by pot machine was studied.

Table 3 Particle size distribution of pot-mixture

Sieve opening (mm)	Cumulative weight			
	Machine filling		Traditional filling	
	Weight (g)	%	Weight (g)	%
6.30	346	81.8	425	79.5
2.00	979		893	
0.70	1 635		1 589	
0.50	1 726	18.2	1 832	20.5
0.25	1 840		1 879	
0.11	1 943		1 913	
0.00	2 000		2 000	

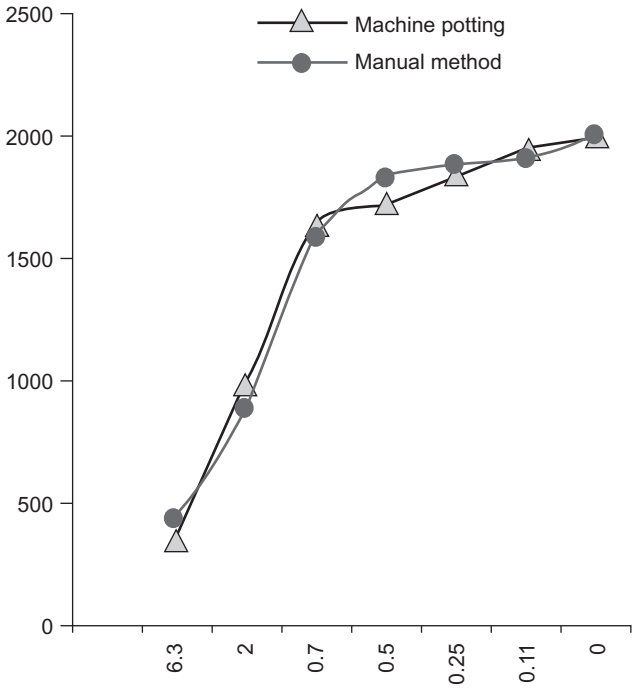

Fig 2 Particle size distribution of pot-mixture

Table 4 Comparison of basic properties of pot-mixture

	Property	Soil: Sand: FYM @ 2:1:1 v/v		Soil: Granite powder: FYM @2:1:1v/v	
		Manual	Machine	Manual	Machine
Physical	Bulk density, g/cc	1.05	1.13	1.11	1.07
	Particle density, g/cc	1.77	1.82	2.05	1.83
	Water holding capacity, %	35.5	31.5	37.4	36.8
Mechanical	Fine sand content, %	32.3	34.3	21.9	23.1
	Course sand content, %	35.9	33.8	29.4	27.1
	Silt content, %	30.5	30.6	44.4	44.1
	Clay content, %	1.3	1.3	4.3	5.7

The physical properties, viz. bulk density, particle density, water holding capacity, and mechanical properties, viz. fine sand content, course-sand content, silt content, and clay content were analyzed. It is found from observations that the physical properties and mechanical properties of the machine made pot-mixture is on par with the hand-made pot-mixture and hence it is concluded that the machine made pot-mixture is suitable of growth of seedlings.

Germination test

A germination study was conducted with the machine made pot-mixture to find out the effect of quality of machine made pot-mixture on seedling growth and root development. The observations showed that seedling growth and root development were on par with the hand-made pot-mixture. Hence it is concluded that there is no adverse effect observed

with the machine made pot-mixture on the establishment of seedlings.

Cost economics

The machine capacity was 100 kg/h which denotes 1 600 bags of 500-g capacity can be filled in a day of 8 hr by engaging two labourers, while only 300-350 bags were filled in the conventional method. Bagging of 1 000 bags through machine costs ₹ 320 while it is ₹ 1 140 manually which worked out 71.4% cost-saving and 80.2% time-saving through machine-filling. Break-even point for utility of this machine is 63 tonnes/annum and pay-back period is 1.4 year. The machine is recommended for nursery-holders around the nation since the machine can provide pot-mixture for development of saplings of 30 000 numbers per month in a commercial nursery.

(a) The pot machine developed enables easy mixing, pulverizing, and vending the pot-mixture in polybags in a desired quantity. The mixing index, pulverization, and aggregate analysis of the pot-mixture prepared by this machine is meeting out agronomic standards. Ninety per cent accuracy is maintained by the electronic vending unit during dispensing of pot-mixture in polybags. Germination percentage of the planting material and root development with the machine made pot-mixture is on par with manual pot-mixture.

(b) The electronic vending is the novel approach adopted in this machine. This vending unit fills the pot-mixture at set quantity (250g, 500g, 1 000g, etc.) at set timing with 90 per cent accuracy.

(c) The machine is recommended for nursery-holders around the nation since the machine can provide pot-mixture for development of saplings of 30 000 numbers per month in a commercial nursery.

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