DEVELOPMENT AND TESTING OF POTTING MIXTURE FILLING MACHINE FOR FILLING GROW BAGS

By

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(2017-18-007)

Thesis

Submitted in partial fulfillment of the requirement for the degree of

Master of Technology

In

Agricultural Engineering

(Farm Machinery and Power Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Farm Machinery and Power Engineering

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TAVANUR-679573, MALAPPURAM

KERALA, INDIA

2019

DECLARATION

I, hereby declare that this thesis entitled **"DEVELOPMENT AND TESTING OF POTTING MIXTURE FILLING MACHINE FOR FILLING GROW BAGS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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ACKNOWLEDGMENT

With whole heartedness I thank '**God the Almighty**' for the help, rendered through various hands, which helped me to the completion of this endeavor.

None other than my guide **Dr. Jayan P R.** *Professor and Head*, Dept. of FMPE, KCAET, Tavanur deserves at the second place, my heartfelt thanks for his persistent initiation, efficacious advice and zealous intellectual support.

I am greatly indebted to **Dr. Shaji James P**. *Professor,* Dept. FMPE, ARS, Mannuthy for his interest and kind advice given to me at all stages of our studies.

I express our heartfelt thanks to **Er. Shivaji. K.P**. *Assistant Professor,* Dept. of FPME, KCAET Tavanur, for is valuable suggestions and motivation.

I place my special thanks to, **Dr. Dhalin D**. *Assistant Professor*, CoA, Vellayani and **Dr. Moosa P.P**, *Assistant Professor,* Dept. Soil Science and Agrl. Chemistry, RARS Pattambi for their suggestions and invaluable help during my study.

Words do not suffice to express my gratitude to all our seniors especially and all our **classmates and friends** especially **Dr. Sarathjith M.C, Er. Besavaraj and Er. Amrutha K** who have helped me immensely during the period of my study and the research work.

I sincerely express our gratitude to all technicians of the Workshop, KCAET, Tavanur, especially **Mr. Lithin,** for his help to complete this project.

I am really grateful to **Er. Sariga**, *Teaching assistant*, FAPE, KCAET for her sincere helps and opinions during the execution of the project work.

I would like to place my special thanks to my junior **Er. Harikrishnan M.P,** for his sincere help and support during my research.

I am thankful to all the **department staffs and faculties** of KCAET, Tavanur for their cooperation and kind advices.

I express my thanks to all the staff members of **library, KCAET Tavanur** for their ever willing help and co-operation.

I am greatly indebted to my **parents** for their blessings and prayers and support without which I could not have completed this work.

I am thankful to **all those**, who directly or indirectly helped me.

AMAL DEV J

DEDICATED TO

THE PROFESSION OF AGRICULTURAL ENGINEERING ...

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SYMBOLS AND ABBREVIATIONS

Symbols	Abbreviations
ϕ	Diameter
%	Percent
±	Plus or minus
^{o}	Degree
<	Less than
>	Greater than
A	Ampere
ANOVA	Analysis of variance
cm	Centimeter
CEC	Cation exchange capacity
CRD	Completely Randomized Design
Dept.	Department
DF	Degrees of freedom
$dS.m^{-1}$	Deci siemens per metre
EC	Electrical conductivity
e.g.	for example
Er.	Engineer
et al.	and others
etc	et cetera
Fig.	Figure
FMPE	Farm Machinery and Power Engineering
FYM	Farm yard manure
g	Gram
G.I.	Galvanized iron
h	hour(s)

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hp	horse power
hz	Hertz
i.e.	that is
IS	Indian Standards
J	Joule
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilo gram
kg h^{-1}	Kilo gram per hour
kW	Kilo watt
kW h	Kilo watt hour
l	Litre
m.c	Moisture content
min	Minute(s)
mm	millimeter(s)
m	Meter(s)
m s^{-1}	Meter per second
M.S.	Mild steel
No.	Number
Pa.s	Pascal – second
RBD	Randomized Block design
rpm	Revolutions per minute
Rs	Rupees
s	second(s)
Sl.No.	Serial Number
v	volt
^{0}C	Degree Celsius
viz.	As follows
Wb	Wet basis

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INTRODUCTION

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CHAPTER I

INTRODUCTION

Preparation of good quality potting mixture is essential for achieving maximum crop yield. There is an increased demand for potting mixtures for horticultural, plantation and forestry crops nowadays as more and more people have come forward showing interest in agriculture. Moreover, cultivating vegetables in homesteads is getting wider acceptance through various interventions of Government agencies in the state. Among the various vegetable growing practices in home stead, grow bag cultivation become widely accepted due to urbanisation in Kerala. Cultivating a crop in open field is easy and more productive is possible if sufficient land, water and effective crop management are made available. Due to fragmentation of agriculture lands, homestead cultivation becomes the only solution to promote the agriculture for sustainable food production. In order to meet the need for these types of cultivation, fruits, vegetables and ornamental plants are well grown in grow bags. Grow bag cultivation of vegetables is getting very popular due to the desire of the people to produce "safe to eat vegetables" at home.

Grow bags are plastic or fabric bags that are used to grow plants with shallow roots. They are ideal for balconies or small gardens, where space is a premium. They are generally made of poly bags of 150 micron thickness. These bags are available in various sizes. In case of short rooted crops, small sized grow bags can be economical as it saves growth medium. They are also re-usable and generate very little waste, at the end of the growing season we could rinse them out and use them again. At the end of the growing season, spent medium provides a very good mulch to spread on the garden. Grow bags are less expensive than rigid containers, and a great alternative to a raised bed. They are also portable and can be placed in a variety of locations. They can be put on a balcony, outside in a garden, or in a greenhouse. The amount of sunlight and warmth required by the grown plants is considered while choosing the location. Plants grown in these bags are watered often as it typically require more water than potted plants. The plastic heats the mix up considerably, so keeping the soil moist is essential for the growing plants to succeed. Grow bags can be used in a greenhouse instead of planting directly into the ground. This also protects them for soil borne diseases.

Shallow-rooted plants are ideal in the bag because they will not be stunted by the bottom of the bag. Good choices include tomatoes, peppers (capsicum), eggplants, zucchini, cucumbers, strawberries, French beans, lettuce, potatoes, herbs, and flowers. Hence the grow bag cultivation is becoming popular in the state. Also, in the agronomical perspective, the establishment of seedlings in the grow bag results good control of pest and disease which results an assured crop yield.

For grow bag cultivation, a proper media should be prepared for the chosen plant, establish the plant, and provide proper care for the entire duration of the crop. Soil, coir pith and farm yard manures (S: C: FYM) are mixed in the ratios 1:1:1 or 1:0.5:1. A potting mix must have ingredients like coir pith so that it retain moisture. Coir pith is highly porous and has less weight when compared to sand. These proportions assure good air flow, drainage and water holding capacity of the soil. Preparation of potting mixture and filling the grow bags uniformly is a crucial task. Mixture is only filled to up to 3/4 th portion of grow bags in order to facilitate proper watering. The filling of the mixture in grow bags is carried out manually in almost all nurseries of horticulture, forestry and plantation under Government/ private sectors. About 300-350 bags weighing 500 g are filled in a day of 8 hours by a single labour. Both men and women labourers are engaged for collecting, pulverising, mixing and filling the ingredients in the grow bag. These operations are done in unscientifically and carried out in bending posture of the labourers. More energy and time are spent and hence it is a tedious and tiresome work.

A few research works were reported in this area. The commercial models for filling the grow bags available are of exorbitantly high costs, which are suitable for large commercial nurseries. KAU has developed a manure pulverizer for pulverizing dried goat faecal pellets, neem cake, cow dung etc. which is getting

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wide popularity among farmers and is a boon to organic farming of the state. The development of a suitable machine for preparation and filling of potting mixture in grow bags of all sizes is the real need especially for homestead vegetable cultivation and for commercial nursery. Hence, a research work is proposed to develop a machine for filling potting mixture in grow bag. The main objectives are

i. To study the soil-mixture and machine parameters for grow bag filling.

ii. To develop a potting mixture filling machine for filling grow bags.

iii. To test and optimize the performance and economics of the developed machine.

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REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the research works related to potting mixture filling, machines developed in this aspect and the evaluation of different kinds of potting media formulated. Various pulverizing and filling machines are reviewed. Works related to different physical and chemical properties for the evaluation of potting media, the methodology adopted to determine those properties are discussed in this chapter.

2.1 Performance evaluation of related machines

Ota *et al.* (1973) developed an apparatus for filling and packing soil in containers for seeds or plant seedlings at a pre-determined volume of soil at a preferred density. The apparatus facilitated the compression of the soil in the containers by pressing the lower lap of a conveyor belt downward and to pack the soil in the container and making an opening in that. Soil was filled in the containers maintaining uniform density and there were uniform growth of seedlings in those containers. Those grown seedlings could be comfortably transplanted manually or mechanically to the ground.

Scata *et al.* (1992) developed an apparatus for edgewise stacking flat single objects from a belt conveyor system or the like into a container or a fixed or mobile stacking system. It employed a moving container mounted on its side in front of an output module of a sorting system and moving downwardly at a governed rate. The inclined container categorised objects and guided into the container by an inclined flat bottomed chute having a single rib at its lower edge. Those objects were flat wise loaded into the container. When the inclined container became upward, those objects were loaded edgewise and the orientation and face were maintained.

Archer *et al.* (1996) developed a system and mode for automatically feeding, inspecting and diverting tablets for continuous filling of tablet containers. It comprised a tablet conveyor system that separates the tablets in a plurality of tablet streams for inspection by colour, size and shape. After the tablet inspection, every tablet passed through a tablet diverter that redirected the tablets to recycle streams, reject stream or one of two bottle filling positions depending on the instruction from the inspection. A bottle conveyor system was equipped which fed empty bottles into a bottle escapement mechanism that sets the empty bottles to be filled. From the bottle escapement mechanism, the filled bottles were filled guided to an exit conveyor. The system was regulated by computer and different control mechanisms to entitle the system to be absolutely functioning without worker's assist.

Greer (1999) developed a hopper for filling bags and it contained a mobile dispensing device capable of bagging of fluent solid materials such as sand. The device comprised a hopper sustained on wheels and included a trailer hitch. Three augers carried fluent material into three chutes. A clamp was set for the chutes to support a bag when it gets filled. An on-board engine and a transmission discriminatingly driving each auger were included in the device. Each chute had pedals for operating their specific clamps and attach their specific auger to the transmission using an electric clutch. The hopper consisted of side doors and rear doors. A detachable ramp was connected at the rear door of the hopper. An open grate constituted a floor inside the hopper. Shelves were given inside the hopper.

Nwaigwe *et al*, (2012) conducted a study on design construction and performance evaluation of a modified cassava milling machine. The study aimed at the development of a modified milling machine that mingle both the impact and shearing milling operation with a pneumatic conveying and clarifying operation. The machine comprised of an electric motor, pulley, belt, a shaft, bearings, the mild steel plates, mild steel angle bars and mild steel cylindrical tube. Selection of these parts was related to the power requirement in the milling of dried cassava chips into flour. A milling efficiency of 82.3 percent was achieved by the machine, and was of dust free. Besides, suited air circulation facilitated the machine to preserve the cassava flour, from the destruction through overheating. The resulted cassava flour had a fineness modulus of 0.31, uniformity index of 0: 1: 9 (coarse: medium: fine) and effective size (D10) of 0.075 mm which were considered to be better than that made by an existing hammer mill with flour of fineness modulus 2.32, uniformity index (U) of 4:1:5 and effective size (D_{10}) of 0.085 mm.

Nwogu *et al*, (2013) conducted a study on an improved design of a flour milling machine. The objective of the improved design was to enhance the milling of flour to a higher degree which in turn aids in food production without damaging the nutrients contained in it. The main components of the milling machine include main frame, rollers, gears, table, electric motor mounting frame, smooth rods, drive shaft, pulley drive, motor, belts, key, ball bearing, nuts and bolts. It was mentioned that the old design of milling machine didn't have the pinion drive gear and thus the reduction in speed was achieved with the use of an auxiliary gear box which was actuated by an automotive engine of 60 hp. The modified machine was designed to use the main drive shaft as means of speed reduction. Also the cost analysis of the improved design of machine was evaluated. Above all, the performance of the machine was recorded as satisfactory.

Shakiru *et al*, (2014) performed a study on assessment of dry and wet milling using fabricated burr mill. The purpose of the assessment was to analyze the reductions in the size of agricultural products during wet and dry milling. A survey was also made in three markets for evaluating the burr mill used in reduction process of agro materials. They constructed a pepper grinding machine with a burr plate having a thickness of 9.47 mm. Tests were performed to evaluate the milling effect of beans, maize, pepper, vegetables like tomatoes etc. with or without adding water. A diesel engine was used as a prime mover. Around 65 percent of diesel was used for wet milling while 35 percent for dry milling. The study revealed that the level of wear and tear of the machine varied with the age of machine and frequency of usage. The thickness of the plate after the successive usage was found to be 4.69 mm in thickness.

Selvan *et al.* (2015) designed, fabricated, and tested a power operated continuous-run machine to master seedling-nursery management capable of mixing, pulverizing, sieving, and filling of pot ingredients in poly bags. The developed machine was a vertical free standing unit supported on four legs. Main components included a 3 hp motor, feed-hopper, pulverizing chamber having 8-numbers of paddles, sieving compartment worked by slider-crank mechanism, vending instrumentation, and outlet. Potting ingredients such as soil, sand, granite power, farmyard manure, and compost were used for preparation. Those materials were fed from the top and the resulting pot-mixture was obtained at the bottom. An electronic vending was the novelty of the potting machine developed, which controlled filling of the pot-mixture at fixed amounts at fixed time-gap. When compared with the manual method, more proportion of about 81.8 per cent of acceptable level of aggregate was obtained with machine. When bagging done with the machine, it resulted in 71.4 per cent cost-saving and a time-saving of 80.2 percent.

Jayan *et al.* (2017) conducted a study on performance evaluation of KAU Manure Pulverizer. It was tested to determine its performance and to optimize the machine and material parameters. Dried manures were fed into the pulverizing drum from hopper through feed chute and it got pulverized due to the rotation of pulverizing blade. Performance of the pulverizer was evaluated for different dried manures at different moisture contents. The capacity of the pulverizer was 500.00 kg h^{-1}. Efficient moisture contents obtained for cow dung, goat faecal pellet and neem cake are as 20.93, 16.70 and 14.20 per cent respectively. Time of operation increased with the increase in moisture content and increase in sieve size except in the case of cow dung. The analysis indicated that maximum efficiency of 98.5 per cent was obtained for the goat faecal pellets at 15 mm clearance and at 5 mm sieve size. With 10 mm sieve size maximum efficiency of 99 per cent was obtained for goat faecal pellets. The least efficiency was observed for both cow dung and neem cake. The complete testing and analysis indicated that KAU manure pulverizer with 5 mm sieve and 15 mm clearance performed efficiently for all types of dried manures.

2.2 Evaluation of potting media

Goh and Haynes (1977) evaluated the potting media for commercial nursery production of container-grown plants. The study aimed to the determination of physical and chemical properties of the potting media and their ingredients. About three types of potting media with peat-sand, peat-sand-sawdust, and peat-sand-soil were used for the study. Particle density, bulk density, porosity, air capacity and water holding capacity were the physical characteristics and pH, cation exchange capacity (CEC), soluble salt percent and carbon-nitrogen ratio were the chemical characteristics determined in the study. Sawdust media had a high total pore space, air space, percent pore space, and air capacity but had low water holding capacity. But in peat-sand-soil media, soil properties were not shown and these media possessed air and water characteristics alike to those for the peat-sand media. On other hand peat and sawdust was with a low pH, sand with high pH, and soil having a moderate pH. Sand and sawdust exhibited extremely low value of CEC. Soluble salt levels of all the three media prepared and their ingredients were found to be low and also even lower than the critical levels. Sawdust exhibited unusually high C/N ratio and that was pondered in high C/N rates in peat-sand-sawdust media.

Johnson *et al.* (1980) evaluated potting-media, fertilizer source and rate of application on chemical composition and growth of *ligustrum japonicum* thunb. The analysis was designed to measure the interaction of media combinations and 3 forms of fertilizers on nutrient leaching losses and growth of *japonicum* plants. Canadian peatmoss: pinebark: sand by volume, fertilized with a resin coated, liquid or granular 18:6:12 fertilizer at 1350 or 2700 kg.N.ha.year^{-1}. Rooted cuttings were planted in one of 4 media: A (0.5:1:1); B (1:1:1); C (2:1:1); D (4:1:1). Highest cation exchange capacity was obtained for A by volume of all media prepared and thus contributed to the best growth of *japonicum* for all fertilizers used. Liquid and resin-coated fertilizer exhibited ideal top growth with least leaching.

Bugbee and Frink (1986) conducted a study on aeration of potting media and plant growth. The main objective of the study was to determine aeration in pots

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filled with media to identical depth and to report the variation of physical characteristics of media and the growth of plants for change in aeration. A 1:1 peat-vermiculite potting medium by volume was fitted to aerations of 1.0, 2.2, 5.0, 11.3, 13.3, 20.0 and 33.6 percent volume by varying the size of particles of the two ingredients. Whole pore space persisted constant as aeration increased, but total moisture holding capacity dropped linearly. When water kept over a matric potential of -30 cb was increased lightly until aeration attained 10 to 15 percent and then dropped. When water kept under a matric potential of -30 cb was decreased curvilinearly with increased aeration. While the plants differed in their responsiveness to aeration, plant growth for aeration 5 percent volume and below was found to be restricted. Plants broadly show a satisfactory aeration range of 11.3 to 20.0 percent volume and a slight decline in growth was obtained at the topmost aeration of 33.6 percent volume.

Perera *et al.* (1996) conducted a study on improvement of seedling quality in polybags through manipulation of potting media. The study was designed to check the hypothesis that seed nuts grown in a pre-nursery and afterwards grown in a river sand potting media would react best to fertilizer application. It also aimed to develop and propose an appropriate package to enhance the nutritionally inferior media. Potting mixtures with varied proportions of river sand were used to grow coconut seedlings' in poly bags with and without fertilizer and also focused to assess the growth and vitality after seed nuts were permitted to germinate on a pre-nursery bed and later they were transplanted. Top soil replaced in the poly bag media with river sand did not shown any significant effect on the development of coconut seedlings. It was realised that pure river sand exclusively might be effectively used, on condition that seedlings were held free from water deficit and in this regard, seed nut laying for the first seven months was considered to be crucial. The height and girth of seedling were found to be better with the utilization of fertilizers. But this effect was found to be significant only five months later seed nut laying.

Khan *et al.* (2006) evaluated the effect of potting media for the production of rough lemon nursery stock. The aim of experiment was to study the physical and chemical properties of various potting media combinations. Also their effect on the growth and development of rough lemon nursery plants established in containers. Leaf manure, peat, spent compost of oyster and button mushroom were combined in various proportions with soil, sand, leaf manure and farmyard manure (FYM). While comparing different combinations, the silt alone shown high value (1.25 $g.cm^{-3}$) of bulk density and also shown highest moisture percentage (58.14 percent). Sand, peat and spent compost (button mushroom) achieved the lowest value (0.80 $g.cm^{-3}$) of bulk density. Total porosity was found to be higher (0.90) for sand, silt, and leaf manure and silt and spent compost while silt alone achieved the lowest total porosity (0.63). While considering pH values, sand and peat exhibited the lowest pH value of 6.5 and the highest pH value of 8.02 was obtained for spent compost of button mushroom with sand. The lowest electrical conductivity value of 1.65 $dS.m^{-1}$ was resulted in sand and peat while the highest (6.29 $dS.m^{-1}$) in sand and spent compost of button mushroom. Mortality percentage was reported lowest (8 percent) for plants raised in sand and peat (1:1) and it was highest (58 percent) for sand and soil and F. Y. M (1:1:1). It was concluded that sand and peat (1:1) could be considered a better potting medium accompanied by sand, peat and spent compost of Button mushroom (1:1:1).

Thankamani *et al.* (2007) evaluated nursery mixture for planting material production in black pepper. The experiment was conducted at Peruvannamuzhi (Kerala) to examine the feasibleness of adopting soil-less medium with coir pith compost and granite powder, in order to plant black pepper (*Piper nigrum*) cuttings in nursery. Plant height, leaf production, leaf area and total dry matter production were found to be higher in 1:1 combination of coir pith compost and granite powder. Also *Azospirillum* sp. and phosphobacteria were added to the medium and considered to be a rich nutrient source. Production cost was least for root cuttings in the medium combined with coir pith compost, granite powder, and farmyard manure in the ratio 2:1:1 while on comparison with conventional potting mixture prepared including soil, sand and farmyard manure in the ratio 2:1:1.

Awang *et al.* (2009) evaluated the chemical and physical characteristics of coco peat-based media mixtures and their effects on the growth and development of *celosia cristata.* The treatments comprised of five different formulations of growing media with coco peat (T_1), 70 percent coco peat and 30 percent burnt rice hull (T_2), 70 percent coco peat and 30 percent perlite (T_3), 70 percent coco peat and 30 percent kenaf core fibre (T_4) and 40 percent coco peat and 60 percent kenaf core fibre (T_5), all on volume basis. Initial pH was found higher for T_1 and T_4, but at the end they seemed to be equal. Bulk density and EC marked higher values of 0.12 $g.cm^{-3}$ and 0.48 $mS.cm^{-1}$ for T_2. Media T_2 and T_3 had higher air content but T_2 held the largest volume of available water. Addition of burnt rice hull and perlite into coco peat improved water absorption ability of the mixture. Combining of burnt rice hull (30 percent), perlite (30 percent) and kenaf core fibre (30 percent) to coco peat enhanced air filled porosity. The growth and flowering of *Celosia cristata* were found to be maximum in the media T_2 with better aeration and moisture. It was concluded that chemical and physical properties of coco peat could be enhanced by adding burnt rice hull.

Nayyeri *et al.* (2009) evaluated the thermal properties of dairy cattle manures. The experiments were conducted at temperatures of 40, 50, 60 and 70°C and moisture contents of 20, 40, 60, and 82 percent on wet basis. The specific heat and of manure was found to increase linearly from 1.9925 to 3.606 $kJ.kg^{-1}°C^{-1}$. Similarly, thermal conductivity also had shown an increase in value from 0.0901 to 0.6814 $W\ m^{-1}°C^{-1}$. The increase in the specific heat and thermal conductivity was mostly affected by the changes in moisture content rather than the changes in value of temperature. The thermal diffusivity of dairy cattle manure had shown a change in value from 1.13 to 2.94×10-7 $m^2\ s^{-1}$. It was reported that the increase in the thermal diffusivity was greatly affected by the change in temperature than the change in moisture content. Regression models were developed to compare both the estimated and measured values. It revealed that the accuracy of the equations for thermal properties could be considered as better one for engineers for designing thermal equipments of dairy cattle manure.

Mugloo *et al.* (2010) studied on the interaction effects of growth media, container size and types on the nursery performance of *Melia Azedarach* Linn. Five growing media *viz.,* M_0 : Soil (control), M1= Soil: Sand: FYM (1:1:1), M_2= Soil: Sand: FYM (2:1:1), M_3 : Soil: Sand: FYM: Dalweed (2:1:1:1), M4: Soil: Sand: FYM: Dalweed (2:1:2:1) were formulated for two different container sizes and types viz., root trainers (three size) : 150 cm^3, 250 cm^3 and 300 cm^3 and polythene bags made up of three equal volume as that of root trainers (150 cm^3, 250 cm^3 and 300 cm^3). The whole experiment was laid out in Completely Randomized Design consisting of three replications each. The results revealed that there were significant effects on different parameters of seedlings for container type and growing medium. The root trainer with M4 media combination reported larger values for collar diameter (2.73 mm), fresh root weight (1.41 g), dry root weight (0.35 g), total seedling dry weight (0.082 g), Dickson's quality index (0.070). While M4 media with polythene resulted in larger values of height (30.11), fresh shoot weight (2.32 g), total seedling fresh weight (3.18 g) and dry shoot weight (0.62 g). The combination of M_4 media with root trainer (300 cc) seemed to be the best growing medium amongst all the tested combinations, so to produce good quality nursery stock of *Melia azedarach.*

Kumar *et al.* (2011) evaluated potting media for quality planting materials of litchi (*Litchi chinensis Sonn*). Ten different potting mixtures were formulated with FYM, vermin-compost, vermiculite, perlite, riverbed soil etc. The results revealed that maximum survival (82 percent) was reported for the potting media with river bed soil and vermin-compost in the ratio (2:1) and added with DAP (5 g) having respective 76 percent and 70 percent survival rates. Maximum number of secondary roots and tertiary roots were also recorded. Maximum height (72.6 cm), stem girth (4.16), number of leaves (17) and number of leaflets (58.4) were reported for the media mixed with soil, sand and vermin-compost in the ratio 1:1:1 and DAP (5 g) added along with the mix.

Manickam and Suresh (2011) studied the effect of moisture content and particle size on bulk density, porosity, particle density and coefficient of friction of

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coir pith. The experiments were performed with the coir pith obtained from different coir fibres. Dried coir pith was sieved into different particle size. The values of moisture content, particle size, porosity, particle density, bulk density and the coefficient of friction of coir pith ranged from 10.1 to 60.2 percent (wet basis), 0.098 to 0.925 mm, 0.623 to 0.862, 0.939 to 0.605 $g.cm^{-3}$, 0.097 to 0.341 $g.cm^{-3}$ and 0.5043 to 0.6332 respectively. Certain models were developed to find out bulk density, porosity, particle density and coefficient of friction for different moisture content and particle size. The experimental results revealed that bulk density increased with increase in moisture content and decreased with increase in particle size. On other hand porosity shown a decrease with the increase in moisture content and an increase with the increase in particle size. Particle density of the coir pith appeared to have higher values as the particle sizes decreased and it decreased with the increase in moisture content. The coefficient of friction of coir pith against mild steel decreased as its moisture content increased irrespective of the particle size. When the particle size was reduced, the frictional coefficient also reduced.

Massey *et al.* (2011) conducted a study on chemical and physical properties of potting media containing varying amounts of composted poultry litter (CPL). The objectives of the study consisted of determination of impact of addition of composted poultry litter to the media and the chemical and physical properties of a potting mix. The effect of compost addition on evaporation rate from containers were also evaluated. Four potting media mixes were prepared containing 0 percent, 20 percent, 40 percent, and 60 percent CPL on volume basis. Chemical analysis was performed for the determination of the following mineral concentrations: nitrogen (organic and soluble), P_2O_5, K_2O, Ca, S, Mg, Mn, Cu, Zn, and Na. The aeration porosity, total porosity, water holding capacity and bulk density of the four media were calculated with a chamber that was designed in order to enhance measurement of the physical properties of media. The results indicated that there was a decrease in aeration porosity, and total porosity when the percentage of compost in potting media increased. While the volumetric water holding capacity was not significantly affected by the addition of CPL but increased valuable plant nutrients and minerals. It was reported that addition of CPL did not affect the evaporation rate, but increased the mass of water in a pot at all water contents. The addition of 20 to 40 percent of CPL was recommended for formulating a quality potting media.

Gautam and Ashwath (2012) conducted a study on hydrophobicity of 43 potting media and their implications for raising seedlings in re-vegetation programs. The objectives were to test the variability in hydrophobicity of selected potting media and to determine the relationships between hydrophobicity and media physical, chemical and biological properties. The test revealed that hydrophobicity decreased with an increase in moisture content of the media. Significant ($P < 0.05$) negative correlation was seen between hydrophobicity and pH ($R_2 = 0.92$) and also with hydrophobicity and water holding capacity ($P < 0.05$) of the media ($R_2 = 0.89$). However, no significant correlation was observed with electrical conductivity of the media ($R_2 = 0.03$). The media wettability as determined by FTIR spectroscopy was found to be significantly ($P < 0.001$) higher in non-hydrophobic media than in hydrophobic media. Also the number of wax degrading bacteria was found to be similar in both the media. The results revealed that majority of potting media were found to be hydrophobic in nature and it affects the survival of seedlings in the field.

Handreck (2013) studied the properties of coir dust, and its use in the formulation of soilless potting media. Two coir products - Coco Peat (CP) from Malaysia, and Palm Peat (PP), from Sri Lanka and a peat (SP) from Russia, were chosen. The three coir dusts were analysed to evaluate chemical and physical properties. Estimation of concentrations of nutrient elements and the values of pH, E.C, CEC and porosity of coir dusts were measured. The analysis revealed that about 10 $mg.l^{-1}$ extra N per week must be provided to medium. The K content was high while Cl content was moderate. The low CEC of the coir products compared with peat shown their lesser ability to retain cations and to buffer against pH change. Two coir products had minimum air-filled porosities than the peat and they retained more water at 10 kPa suction.

Khomami *et al.* (2013) studied the feasibility of sawdust vermin-compost applicationt as potting media on growth and nutrition of Dieffenbachia Amoena 'Tropic Snow'. The objective was to evaluate sawdust vermin compost properties to use it as a potting media. It also aimed to judge the growth of Dieffenbachia Amoena 'Tropic Snow' plants. Potting media comprised of peat (PE), vermiculite (VE), perlite (P) in the ratio 6:3:1 and among these materials, peat was substituted with 0, 10, 20, 30, 40, 50 and 60 percent (by volume) sawdust (SV). The maximum growth of the plant was resulted from substitution of 60 percent SV instead of peat in PE: VE: P (6:3:1) potting mixtures. Positive correlations marked between the increased growths of plant with the concentration of N in leaf tissue of plant.

Paramanandham *et al.* (2013) conducted a study on influence of sequential washing on the pH and electrical conductivity of graded coir pith. It was aimed to assess the pH and electrical conductivity (EC) of coir pith during sequential washing. The pH and conductivity were determined using aqueous extracts of graded raw coir pith with pH meter (HI2215pH/ORP Meter) and conductivity meter (Conductivity meter 304) which expressed the value in $mS.cm^{-1}$. The pH ranged from 5.97 to 8.02, 5.98 to 8.05, 6.74 to 8.24 and 6.52 to 8.38 respectively in four different grades (0-200 μm; 200-500 μm; 500-850 μm and above 850 μm) of coir pith. The results indicated that the hydrogen ion concentration was low in unwashed and first washed coir pith and high in final washed. While EC was high in unwashed and low in seventh washed coir pith extract. The final washed coir pith could be selected for future experiments as a suitable pH and EC had been obtained. The investigation concluded that pH and EC were the vital influencing factors that decide the quality of any soilless media.

Surywanshi *et al.* (2013) conducted a study on organic manure based potting mixtures for quality seedling production in *Oroxylum Indicum* (L.) vent. The study was aimed to evaluate seven organic based potting mixtures on seedling growth and vigour in *Oroxylum indicum.* FYM, forest soil, vermicompost, poultry manure, neem cake were used along with mixture of soil and sand in 1:1 proportion. The experiment was laid out in Randomized Block Design (RBD). It included four replications having 25 seedlings each. Various potting mixtures such as soil alone, soil and sand in 1:1 ratio, soil and sand with farm yard manure (2:1:1), vermin compost (2:1:½), poultry manure (2:1:0.5), neem cake (2:1:0.5) and forest/ habitat soil (2:1:0.5) were formulated and evaluated for the study. Seedling growth and biomass were reported larger in mixture with soil, sand and vermin compost in the proportion 2:1:0.5. It was followed by soil, sand and farm yard manure mixture with ratio of 2:1:1. Theses potting mixtures were recommended for commercial production of quality seedlings of *O. indicum.*

Konlan *et al.* (2014) presented a study on the topic evaluation of river sand as a medium for raising cocoa seedlings. The main aim of the experiment was to investigate the effect of employing river sand and river sand-topsoil mixture on cocoa seedlings. The test was laid out in a randomized complete block design with four replicates and five treatments. Treatments tested were with sole topsoil, sole river sand, river sand + foliar fertilizer (Sidalco liquid fertilizer, NPK-10:10:10), river sand + topsoil (1:1) and river sand + topsoil mixture (1:1) + foliar fertilizer. The results indicated that sole topsoil retained more moisture and obtained taller seedlings. The river sand-topsoil mixture + foliar fertilizer seedlings had higher percent of chlorophyll content. It was considered to be photosynthetically efficient and resulted in significantly ($P<0.05$) higher stem diameter. Stem volume of those seedlings grown in the media with river sand, topsoil and foliar fertilizer were similar as in the case of sole topsoil medium. Positive correlations were obtained when moisture retention and chlorophyll content of the seedlings were taken into consideration. Chlorophyll content exhibited a positive correlation with stem diameter and height of the seedlings. It was therefore concluded that cocoa seedlings can be grown in polybags filled with a mixture of river sand and topsoil (1:1) for a period of six months provided foliar fertilizer is applied at the rate of 10 ml NPK (10:10:10) in 15 litres of water at bi-weekly intervals.

Kumar *et al.* (2014) conducted a study on the evaluation of alternate potting media mixtures for raising quality planting material of litchi in polybags. An experiment was formulated using various potting mixtures substrate with an aim to standardize the ideal potting media combination. Riverbed soil, vermi-compost (2:1) and NPK (5 g/sapling) or riverbed soil, vermi-compost (2:1) and vermiculite (50 g/sapling) was recognized as the ideal potting media. Maximum survival, collar girth, sapling height, number of leaves and number of leaflets at 8 months of planting were obtained. Similarly maximum fresh weight, dry weight of shoots, higher root colonization of secondary and tertiary roots, fresh plant biomass, dry plant biomass and fresh root shoot proportion were reported in river bed soil and vermi-compost (2:1) with NPK (5 g/sapling) whereas, dry root shoot ratio was higher in river bed soil and vermi-compost in the ratio 2:1.

Sharif *et al.* (2014) presented a study on standardization of potting media for nursery raising seedlings of jujube (*Zyzyphus mauritiana* Lamk). The objective of the study was to assess the ideal growing media combination and to estimate the media nutrient composition needed. Silt, coconut fibre, bagasse and farm yard manure in ten different proportions were prepared to grow per seedlings. The maximum water holding capacity (41.34 percent), air filled porosity (16.47 percent), EC (1.85 $dS.m^{-1}$), germination percentage (86.33 percent), maximum number of leaves (123.36), maximum number of sprouted shoots (8.14) maximum number of roots (69.11) were recorded in a media with canal silt (45 percent) and bagasse (45 percent) along with 10 percent of coconut husk. But it was acidic in nature with a pH value of 6.45. Success ratio after transplantation in field was found to be great (92.89 percent).

Gupta and Dilta (2015) conducted a study on effect of growing substrates and pot sizes on growth, flowering and pot presentability of primula malacoides franch. The experiment was laid out in Completely Randomized Design (factorial). It comprised of evaluation of seven potting media in different proportion by volume. They were as soil, FYM and sand (1:1:1), ban oak leaf mould, FYM and soil (2:1:1), Rhododendron leaf mould, FYM and soil (2:1:1), Rai, FYM and soil (2:1:1), Chirpine leaf mould, FYM and soil (1:1:1), coco peat, FYM and sand (1:1:1) and spent mushroom compost, FYM and sand (2:1:1). Three pots with sizes 15, 20 and 25 cm in diameter were used. The media with coco peat, FYM and sand (1:1:1) reported higher plant height, plant spread, number of inflorescences per plant, number of flowers per plant, duration of flowering and highest pot presentability score. Pot sizes of 25 cm diameter exhibited the same.

Popescu and Monica (2015) conducted a study on the effects of different potting growing media for *Petunia grandiflora* and *Nicotiana alata* Link & Otto on photosynthetic capacity, leaf area, and flowering potential. The study aimed to explain the effects of growing media on these parameters by assessing certain physiological factors, leaf area, and flowering potential of *P. grandiflora* and *N. alata*. Optimization of growing mixture formula for petunia and ornamental tobacco was achieved with four growing media mixed using fallow soil (FS), biolan peat (BP), acid peat (AP), leaf compost (C), and perlite (P) in different ratios. The physiological potential of petunia and ornamental tobacco was examined by photosynthesis and respiration rate and chlorophyll pigments in leaves. On other hand, the vegetative and flowering phonological stages were assessed by number of leaves per plant, leaf area, number of flowers per plant and leaf area/flowers ratio. Highest photosynthesis rate 8.612 μ.mol CO_2 $m^{-2}.s^{-1}$ and leaf area 1.766 dm^2 were achieved in the flowering stage of petunias when growing media with 60% biolan peat, 30 percent acid peat and 10 percent perlite (BP60-AP30-P10) was used. Flowering responses to growing conditions altered largely among plants and the biggest number of ornamental tobacco flowers (22 flowers in plant-1) was recorded as an effect of BP60-AP30-P10 media.

Yadav and Thakare (2015) conducted a study on the topic cow dung for improving the pH of highly alkaline soil and Indian cow importance from vedic scriptures. Garden soil (2 kg each) was filled in 5 plastic pots and water with a pH of 13 was added. Cow dung was added in succession of 200, 400, 600, 800 and 1000 g to plastic pots containing the prepared basic soil. The pH value and electrical conductivity of the media were measured after 15 days and 40 days. Mixing with cow dung shown a decrease in pH value of the basic soil. The experimental test revealed that the initial soil pH was 6.02 and electrical conductivity was 0.117 $mS.cm^{-1}$ and later the addition of basic solution raised the pH value to 8.25 resulting in basic soil which is harmful for normal plant growth. While the addition of cow dung, 15 days pH values estimated showed a decrease and it continued to show a decline at 40 days measurement. Thus cow dung seemed to a good mean for the treatment of highly basic or alkaline soil.

Colombo *et al.* (2016) conducted an investigation on the topic potting media, growth and build-up of nutrients in container-grown desert rose. The aim of this study was to investigate the effect of potting media on the growth and increase in nutrients for desert rose plants. Plants were grown in the greenhouse in prepared potting media with sand and Amafibra 47 coconut fiber (S+CF), sand and Lupa (S+L), sand and modified Lupa (S+ML), vermiculite and Amafibra 47 coconut fiber (V+CF), vermiculite and Lupa (V+L) and vermiculite + modified Lupa (V+ML). Experiment was conducted in fully randomized design with five replications per treatment with one plant in each pot. Shoot height, caudex diameter at the base, leaf, stem and root fresh and dry weight, root system volume and build-up of macro and micronutrients in the roots, stems and leaves were assessed by performing chemical analysis of these organs. The plants grown in S+CF and V+CF mixes recorded higher growth rates and greater nutrients build-up in dry matter and was recommended. It was due to the absorption of high quantity Mn from the mix.

Eed (2016) conducted a study on effect of various potting media on percent survival and growth of jojoba rooted cuttings under greenhouse and shade house conditions. The experiment aimed in the assessment of various parameters such as survival percentage, different growth parameters such as height of plant (cm) and number of branches and leaves per plant were carried out after one month and six months. An additional medium containing peat moss and sand in the ratio 1:1 was mixed for the first experiment. For second experiment, poor grown rooted cuttings in first experiment were transferred to a promising potting media. Experiments were performed in a randomized completely block design (RCBD) with three replicates, each with 10 rooted cuttings per replicate. The results revealed that the maximum value of survival percentage, height of plant (cm) and number of shoots and leaves per plant were achieved by peat moss+ vermiculite+ perlite (1:1:1) medium. But the medium with sand and soil additional to imported medium (peat moss) had a comparative value of studied parameters opposite the previous mentioned medium. Thus, it enhanced the use of above medium for decreasing input cost and achieving higher growth parameters.

Guo *et al.* (2016) studied on the effects of cattle manure compost (CMC) combined with chemical fertilizer on topsoil organic matter, bulk density and earthworm activity in a wheat–maize rotation system in Eastern China. The treatments were prepared as CK without any fertilizer, NPK as 100 percent chemical fertilizer (CF), $NPKM_1$ with 25 percent CMC mixed with 75 percent CF, $NPKM_2$ with 50 percent CMC mixed with 50 percent CF, $NPKM_3$ with 75 percent CMC mixed with 25 percent CF and CM with 100 percent CMC. Except CK, all the five treatments achieved the same N, P and K application rate of 375 kg.N.ha $^{-1}$.yr $^{-1}$, 92.4 kg P_2O_5 ha $^{-1}$.yr $^{-1}$ and 316.3 kg K_2O ha $^{-1}$.yr $^{-1}$. The results validated that organic matter, water content, total N content and earthworm density from topsoil were far and positively ($P < 0.01$) related to CMC media. While a negative correlation was recorded between soil bulk density and CMC input and was significant. The average annual yield of the wheat–maize rotation system significantly increased ($P < 0.05$) in all media compared with CK. The highest yield was reported for NPKM1. Application of CF alone had resulted in declined soil organic matter, water content and total N content. It also ended in negative effects on activities of earthworm while CMC relieved same negative effects.

Saka *et al.* (2016) studied on the effects of different soil potting mixtures on the early growth of Mahogany (Khaya senegalensis). Two potting mixtures, cow dung and poultry dropping were used. A control was arranged to check for fluctuations existing between the two mixtures. Ninety seeds were chosen and were treated with hot water. They were raised in a polythene pot of size 25 cm x 13 cm x 6cm. Pots were filled with three different soil combinations, viz: T_1 (Cow dung + Top Soil + River Sand), T_2 (Poultry dropping + Top Soil + River Sand) and T_3 (Top Soil + River Sand) and replicated ten times. Height, girth, and the number of leaves of seedlings were calculated. It was reported that there was a significant variation among the treatments in the seedlings height and girth. ($p < 0.05$) and no any with the number of leaves produced by the seedlings ($p > 0.05$). Application of poultry droppings to the potting mixtures proved to be essential at the initial stage of germination.

Utobo *et al.* (2016) performed an analysis on evaluating eco-friendly potting media on growth and yield of carrot varieties in Abakaliki, South Eastern Nigeria. The objective was to evaluate the effect of various potting mixture on the growth and yield of carrot varieties and to find the idea one. Different types of potting media were formulated with composted sawdust (CSD), composted rice hull (CRH), cured pig dung (CPD) and solarized top soil (TS) in different ratios by volume. The three carrot varieties used were Technisem (V_1), Lunga rossa ottusa 2 (V_2) and Royal sluis (V_3). Experiment was laid out in 3 x 7 factorial Completely Randomized Design (CRD). Carrot varieties constituted for factor A while potting mixtures for factor B. The result indicated that the varieties were significantly different in vegetative and yield parameters. Lunga rossa ottusa 2 (V_2) achieved the best, followed by Technisem (V_1) and the least was that of Royal Sluis (V_3). It was reported that there were significant effects seen in growth and yield of the three varieties assessed under both the screen house and the field conditions. Medium with composted rice hull, composted sawdust, cured pig dung and top soil seemed to be ideal for both conditions which was followed by the media combination with composted rice hull, cured pig dung and top soil.

Bhasotiya and Tandel (2017) conducted a study on influence of potting mixtures on germination, growth and survival of *Ailanthus excels.* In this experiment, seeds were sown in the polythene bags filled with soil, sand and FYM in eight different proportions. The combinations include T_1 with soil and sand (1:1), T_2 with soil and FYM (1:1), T_3 with soil, sand and FYM (1:2:1), T_4 with soil, sand and FYM (1:1:2), T_5 with soil, sand and FYM = (2:1:1), T_6 with Soil, sand and FYM = (2:2:1), T_7 with soil, sand and FYM = (2:1:2) and T_8 with Soil, sand and FYM =(1:2:2). The experiment was laid out in Completely Randomized Design with 3 repetitions. Largest germination percentage was reported in T_1. Number of leaves per plant, shoot length, collar diameter, percentage survival, fresh and dry weight per plant of seedlings were exhibited on media T_7. But the root length was found best in T_8. While comparing all the mixtures, soil, sand and FYM (2:1:2) ratio seemed to be the best in terms of growth parameters.

Huq *et al.* (2017) evaluated the potting media for rapid growth of mango nursery plants. The objective was to develop a potting medium for mango nursery plants in order to produce high quality plant material. Twelve different potting mixtures were formulated and their capacity to retain healthy growth and to sustain ideal physical properties over time were studied. Formulated media included bagasse, FYM, canal silt and coconut fibre in various proportions by volume. All the combinations were evaluated for plant survival (percent), plant height, stem diameter and the physical and chemical properties of media. The potting medium that recorded largest seedling survival (94 percent) contained bagasse (70 percent), silt (25 percent) and coconut fibre (5 percent). The same combination also obtained a maximum plant height of 60 cm and a maximum stem girth of 1.2 cm. While assessing the various physical and chemical properties of potting mixtures, 38 percent water-holding capacity, 13 percent air-filled porosity, 1300 $\mu S.cm^{-1}$ electrical conductivity and 7.8 pH were recorded maximum for the same medium.

Ilahi and Ahmad (2017) studied the physical and hydraulic characteristics of coco peat perlite mixture as a growing media in containerized plant production. Media contained perlite and coco peat in 3:1 proportion. Bulk density, particle density, porosity, particle size distribution, water holding capacity, wettability and hydraulic conductivity of the media were assessed. Particle size varied between 0.425 and 4 mm in diameter while bulk density recorded a value of 0.09 $g.cm^{-3}$. Total porosity with a value of 79 percent and wettability of the media increased on adding perlite into coco peat. On other hand, a large value of water holding capacity (912.54 percent) and a low value of hydraulic conductivity ($0.1 cm.s^{-1}$). The experiment results affirmed the addition of perlite to coco peat for enhancing the physical and hydraulic characteristics of the media.

Ramya *et al.* (2017) conducted a study on the humidity conditions for rooting and establishment of plagiotropic branches of black pepper (Piper nigrum L) grown in grow bags. An experiment was conducted to standardize an appropriate rooting environment for the production of bush pepper. Potting mixtures with soil and vermin compost in ratio 3:1 and coir pith compost alone and in combination were prepared and assessed for the rooting and establishment of bush pepper with and without humid chambers. There were nine treatments with three replications each. It was reported that after 50 days of planting, maximum number of laterals were recognised in mixture with coir pith compost in humid chamber (T_2 / 63.3 percent) followed by coir pith compost mixture by retaining humidity (T_8 / 60.8).The study revealed that the coir pith compost can be used as medium for rooting and establishing of laterals for large scale production of bush pepper.

Sujitha and Shanmugasundaram (2017) conducted a study on the topic assessment of soil moisture characteristics curve for greenhouse growing media. The objective comprised of the measurements of various physical properties of growing media and to evaluate the water holding capacity of the growing media. Three treatments comprised of soil media (T_1), soil and sawdust (2:1), (T_2) and soil and coir pith (2:1), (T_3). Field capacity, wilting point, soil moisture content, bulk density, particle density, porosity and water holding capacity, soil moisture tension of the mixtures were determined. The experiment exhibited that the bulk density, particle density, porosity, field capacity and wilting point were found out as the highest in T_1 followed by T_2 and T_3. Available water retained in soil pores was by forces that depended on the pore size and the surface tension of water. The narrowly bound particles had the minor pores and had stronger attraction between soil and water. Thus resulted in higher water holding capacity of the soil. On comparison with treatments T_2 and T_3, T_3 seemed to have available water in higher amount due to higher retention capacity of coir pith. The maximum water holding capacity among the treatments were recorded as 65 per cent for T_3 followed by 60 per cent for T_2 and 33 per cent T_1 soil. Hence, the results revealed that the treatment T_2 and

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T_3 exhibited a better performance in greenhouse with 5 percent difference in maximum water holding capacity.

Gohil *et al.* (2018) studied the role of growing media for growing ornamental pot plants. The aim of the study was to present an overview of the effects of different potting mixtures on aspects accountable for the growth of an ornamental plant. Flowering, foliage beauty, compacting of size and ability to survive were determined. It is reported that potting media containing coco peat, sand and vermicompost in the proportion 2:1:1 by volume resulted in best growth and also enhanced quality in aglaonema. It was recommended that rice husk in medium improved optimal growth, aesthetic quality. Soil and vermicompost in equal ratio applied larger number of sprouts per plant in potted dieffenbachia. Chrysanthemum grown in mixture of coco peat, soil, sand and vermicompost significantly contributed to the better result affecting to growth and flowering. Mixture of coco peat, rice husk and vermin compost in the ratio 1:2:1 by volume improved the vegetative growth and supplemented coco peat amplified flower yield and enhanced the quality of gerbera. Orchid achieved better flower yield and quality in media with coco peat. Anthurium achieved best vegetative growth in media of sand and coir pith compost but the media with coco fiber, FYM and neem cake enlightened the flower parameters. Combination of vermin compost and coarse sand in the proportion 3:2 by volume as media was suggested to indorse the flower yield of zinnia.

Hewavitharana and Kannangara (2019) conducted a study on evaluation of organic potting media enriched with *trichoderma* spp. and their effect on growth performance of selected vegetables. The research aimed to develop inexpensive organic potting mixture with chosen problematic invasive plants with agricultural wastes augmented with *Trichoderma* amendment. Also it aimed to assess the physical and chemical properties of the mixture. Three different potting media of coir dust and invasive plants (2:3) as T_1, rice husk and invasive plants (2:3) as T_2 and coir dust, rice husk and invasive plants (1:1:3) as T_3) were formulated. One set of mixture was treated with *Trichoderma* spp. while the other without mixing

Trichoderma and it was used as controls. Effect of *Trichoderma* amended potting media on plant growth was evaluated using *A. esculentus* and *A. viridis*. T_1 showed optimum physical and chemical properties. The maximum growth performance of *A. esculentus* and *A. viridis* recorded in T_1 along with *Trichoderma* amendments at lower ($p<0.05$) disease incidence (5 percent but it showed significantly lower ($p<0.05$) growth in T_2. The study revealed that T_1 medium with *Trichoderma* amendments could be suggested for growing vegetables.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

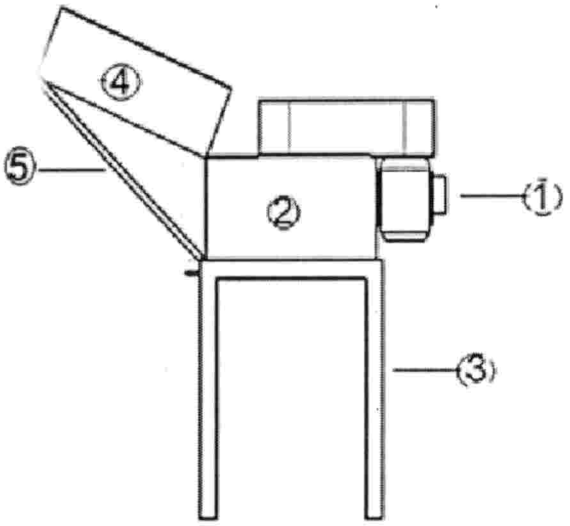
This chapter deals with the study of conventional practices of grow bag filling methods, KAU manure pulverizer, grow bag mixture and machine parameters that affect the grow bag filling. It includes the experimental factors selected for testing and methodology adopted for its performance analysis and the evaluation of grow bag mixture. It also describe the statistical method used for analyzing the performance data and give the description of the cost economics.

3.1 CONVENTIONAL PRACTICES OF GROW BAG FILLING

Traditionally pot media was mixed and filled in grow bags in manually. About 300- 350 bags weighing 500g were filled in a day of 8 hours by a labour (Selvan *et al.*, 2015). Both men and women labourers were engaged for collecting, pulverising, mixing and filling the ingredients in the grow bag. These operations were done unscientifically and carried out in bending posture of the labourers. More energy and time were hence spent and moreover, it was a tedious and tiresome work.

3.2 KAU MANURE PULVERIZER

KAU has developed an organic manure pulverizer for pulverizing dried organic manures. The machine consisted of a 1.49 kW motor as the prime mover, a feeding chute for feeding manures, a pulverizing drum, transmission unit, rotary blades for pulverizing, a sieve and supporting angle frame. The machine was tested and the performance evaluated using different organic manures viz., cow dung, neem cake and goat faecal pellets. The machine was able to pulverize and mix different dried manures. The capacity of the machine was 500 $kg.h^{-1}$. The complete testing and analysis indicated that KAU manure pulverizer with 5 mm sieve and 15 mm clearance performed efficiently for all types of dried manures. It is envisaged to modify this machine by suitably fixing other units for mixing, regulating and filling the grow bags directly.



1. Electric motor
2. Pulverizing drum
3. Supporting stand
4. Feeding chute
5. Angle frame

Fig. 3.1 KAU Manure Pulverizer

3.2.1 Prime mover

A single phase electrical motor having 1.49 kW with 1440 rpm, 230 v, 10 A and 50 Hz was used as a prime mover. Electric motor actuated the shaft consisting of blades through the use of two double V-belt pulleys.

3.2.2 Pulverizing drum

The process of mixing and pulverizing the potting media took place in the pulverizing drum. Soil, coir pith and dried manures were mixed and pulverized by impact and cutting forces of rotating blades. The drum was made up of 5 mm thick M.S sheet and had a diameter of 520 mm and a height of 300 mm. The total capacity of the drum was 0.064 m^3. The drum housed the blades fixed at the bottom of the shaft, bearings and a sieve at the bottom. It had a top cover made of M.S sheet of 1 mm thick, $2/3^{rd}$ of the top cover was fixed and $1/3^{rd}$ facilitated an opening for feeding dried materials. It was hinged to the fixed sector (75 x 20 mm).

3.2.3 Transmission unit

Power from the electric motor was transmitted to the rotating blades using the transmission unit. The unit consisted of two double V-belts pulley of size 10 cm, two B39 V-belts and a M.S shaft of ϕ 35 and length 40 cm. The shaft was fixed inside the drum using two plummer blocks with ball bearings. Plummer blocks were fixed at a distance of 14 cm on an angle iron frame welded to the drum. Rotating blades were fixed at the end of the shaft. A square key of length 6.3 cm was inserted to restrict the relative motion of the pulley and shaft. A lock screw was provided at the bottom to hold the shaft in erect position.

3.2.4 Feeding chute

Soil, coir pith and dried manures were fed manually through the feeding chute to the pulverizing drum. The feeding chute was trapezoidal in shape having 565 cm length and top and bottom width as 72 cm and 30 cm respectively. It was made of a M.S plate of thickness 6 mm. A M.S angle iron 20 x 20 x 2mm was welded at top of the chute and 25 x 25 x 5mm at the bottom to hold the plate in firm condition.

3.2.5 Rotating blade

Rotating blades were responsible for mixing and pulverizing the different potting materials. The rotary shaft was fitted with four blades at the end, inside the pulverizing drum. It had a length of 22 cm and width 4 cm and was made up of EN8 flat of 6 mm thick. The blades were fitted at the bottom of the shaft with the help of a nut and the clearance could be adjusted. It was sharpened on one side at an angle 45°.

3.2.6 Sieve

The pulverized potting media was guided to the hopper through the sieve provided at the bottom of the drum. A 10 mm sieve was used for the operation. It was supported by sheet of size 52 x 2 x 0.4 cm and was welded on the supporting frame and just below the rotating blades. The materials got crushed between sieve and rotating blade to get the fine potting media for filling grow bags. The sieve was of removable type and hence it helped in removing the clogged materials from the holes.

3.2.7 Supporting stand

The entire pulverizing unit viz. electric motor, feeding chute, pulverizing drum, transmission unit and sieve were supported using a stand. It was made with four iron angles of size 50 x 50 x 6 mm at a height of 700 mm.

Plate 3.1 KAU Manure Pulverizer

3.3 PROPERTIES OF RAW MATERIALS AND MIXTURES

Different properties of raw materials viz., moisture content, bulk density, particle density, porosity, fineness modulus, pH, water holding capacity, angle of repose, electrical conductivity and uniformity of the mixture was evaluated using standard test procedures.

3.3.1 Moisture content

It is the amount of water present in the mixture. It was measured using oven dry method (Punmia, 2005). The sample was collected in a clean container and placed in a hot air oven under controlled temperature conditions of 105-110° for a period of 24 hours. The initial and final weights of samples were measured by using an electronic weighing balance having a sensitivity of 0.01g. Moisture content was calculated in dry weight basis and was determined by using the equation,

$$\text{Moisture content, \%} = \frac{[M_1 - M_2]}{M_2} \times 100$$

where, M_1= initial weight of the sample in g

M_2= final weight of the sample in g

3.3.2 Bulk density

Bulk density is the ratio of total mass of the mixture and its volume including the pore volume. It is expressed in g.cm^{-3} and was determined using core rings (Ilahi and Ahmed, 2017). Core rings were pushed into the grow bag mixture until it fully penetrated and excess mixture at the top and bottom of the ring was cut. Weight of the mixture was calculated by subtracting the weight of core ring from the core ring with mixture. Volume of the core was calculated by measuring the internal dimensions.

$$\rho_b = W_b / V_b$$

where,

ρb = the bulk density (g.cm^{-3}

W_b = weight of mixture (g)

V_b =the volume of core ring (cm^{-3})

3.3.3 Particle density

Particle density is the volumetric mass of the solid grow bag mixture. The volume used does not include pore spaces and is expressed in g.cm^{-3}. A certain volume of water was taken in a graduated cylinder. Weighed sample was poured in the cylinder and stirred. The rise in volume was calculated and is the volume of the solid particles. (Thein and Graveel)

$$\rho s = Ws/Vs$$

where, ρs = particle density in $g.cm^{-3}$

Ws = weight of dry sample in g

Vs = volume of sample in cm^3.

3.3.4 Porosity

Porosity is defined as the amount of pore volume in the mixture. If bulk density and particle density were known, porosity could be calculated using the equation,

$$\text{Porosity (\%)} = [1 - (\frac{\rho b}{\rho s})] \times 100$$

where,

ρb = bulk density in $g.cm^{-3}$

ρs = particle density in $g.cm^{-3}$

3.3.5 Fineness modulus

Fineness modulus is an index number which represents the average size of particles in potting mixture. It was found out by sieve analysis using standard sieves. The sieves used for the fine sieve analysis were 2 mm, 1 mm, 600, 425, 300, 212, 150 and 75 μm IS sieves and were arranged in descending order on a mechanical shaker. Oven dried sample was taken on the top sieve and was shaken for at least 10 minutes. Weights retained on each sieve and their cumulative weights were recorded. Cumulative percentage mass retained on each sieve was also calculated and added and divided the sum by 100, which gives the value of fineness modulus. (Punmia, 2005)

3.3.6 pH

It is the measure of hydrogen ion concentration and is the measure of acidity or alkalinity of a solution. A HI9807 pocket-sized pH meter was used for the pH measurement and had an accuracy of ±0.1. It was calibrated using standard pH solutions of 4 and 9. For 10 g of mixture, 50 ml of distilled water was added and was stirred well for about 5 minutes. The suspension was kept undisturbed for an hour and stirred properly and the pH was measured by dipping one the end of pH meter in the extract of the suspension.

3.3.7 Water holding capacity

The water holding capacity is the total amount of water that can be conserved by a potting mixture. The method proposed by Shinohara *et al.* (1999) was adapted for the measurement of water holding capacity of grow bag mixtures. A filter paper was placed in a funnel and a stopper was plugged at the bottom of the funnel. Samples from the grow bags were placed in the funnel, saturated in water at a ratio of 1: 2 (media and water) and was left overnight. When it drained for 3 hours, the remaining sample was oven-dried for 24 h at 105° C. Water holding capacity was calculated using the following formula,

$$WHC,\ \% = \left(\frac{Mw}{Ms} x\ 100\right)$$

where,

WHC = water holding capacity in %

Mw = mass of water retained in the sample (g)

Ms = mass of oven dried sample (g).

3.3.8 Angle of repose

The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the mixture to a horizontal plane. It was measured by filling method using an apparatus consisting of feed hopper with a bottom that could be opened or closed and below an iron disc on which various diameters were marked. Mixture was filled in the hopper and was allowed to heap freely on iron disc by opening bottom. The height and diameter of the cone was measured. Angle of repose was found out using the equation,

$$\text{Angle of repose, } \theta = \tan^{-1}\left(\frac{2h}{d}\right)$$

where, θ = angle of repose in degree

h = height of the cone

d = diameter of the plate

3.3.9 Proportions of potting mixture

Soil (S), coir pith (C) and cow dung (FYM) were used in different proportions of 1:1:1 and 1:0.5:1 by volume for the preparation of grow bag mixture. Evaluation of media prepared helps in determining the best proportion of mix. The effectiveness of the proportions were analyzed w.r.t moisture content, uniformity, electrical conductivity, pH, water holding capacity, porosity, bulk density, fineness modulus and angle of repose.

3.3.10 Electrical Conductivity

Electrical conductivity (EC) in the colloidal mixture is the measure of concentration of soluble salts and gives the salinity in the potting mixture. It was measured using a conductivity meter and expressed in $dS.m^{-1}$. A COM-80, EC/TDS/Temp hydrotester was used for its determination. 40 g of mixture was mixed with 80 ml distilled water and was stirred for 15 minutes and left for an hour. Meter's sensor was dipped into the extract of the suspension and the reading was obtained.

3.3.11 Uniformity

Three different dried materials viz., soil, coir pith and cow dung were pulverized and mixed using the machine. In order to prepare a proper mixture, the materials should be mixed uniformly and finally get filled in the bags. Soil, coir pith and cow dung varied in bulk density. The materials were pulverized separately and mixed properly to obtain a mean reference value of bulk density of the mixture. Such reference mixtures were prepared at different values of moisture content, clearances. The percentage change in the values of bulk densities of the grow bag mixtures prepared at the stipulated conditions were then evaluated with the reference values of bulk densities. Samples of mixtures were collected from the top middle and bottom of properly filled grow bags randomly. Bulk densities were then measured and assigned a positive sign for a larger value and a negative sign for the smaller values to compare different portions within bag. The percentage deviation of bulk densities of the samples of top, middle and bottom from reference bulk density prepared were compared to evaluate the uniformity of the mixture obtained.

3.4 MACHINE PARAMETERS AFFECTING GROW BAG FILLING

The machine parameters affecting the filling of grow bags includes the size of the sieve, clearance between the blade and the sieve and the rotational speed of the blades.

3.4.1 Sieve size

Size of the sieve was measured using an inside caliper and was observed as holes of ϕ 10.

3.4.2 Clearance between sieve and blade

The clearance between the sieve and blade was varied and was measured using vernier caliper. Different clearances were provided using a 5 mm thick bush inserted between the sieve and the blade. Thus, clearances were changed to 15, 20 and 25 mm respectively w.r.t different grow bag mixtures at different moisture contents.

3.4.3 Rotational speed

The rotational speed of the blade fitted on the shaft was driven by a prime mover and was recorded by a DT 1236L non-contact type tachometer. The built in laser for non-contact measurement provided accurate measurement up to 2 m away from target. The measurement was carried out by attaching a reflector on a fixed blade. After starting the machine, the tachometer was kept at a desired height and directed the laser to the reflector. The measurement displayed on the tachometer was noted.

3.5 PERFORMANCE PARAMETERS FOR GROW BAG FILLING

The performance of the developed machine was evaluated with weights of bags filled, time for filling bags, capacity of the machine, number of bags filled, energy consumption and efficiency of the machine.

3.5.1 Weight of bags filled

Small, medium and large size grow bags were filled with the mixture and weight of each bag filled was recorded using a digital weighing balance of sensitivity 0.01 g.

3.5.2 Time for filling

The time taken for filling three types of grow bags at different moisture contents, clearances and ratios of mixture were recorded using a stop watch.

3.5.3 Capacity of the machine

Capacity of the machine was calculated as the amount of grow bag mixture obtained at the outlet per unit time. Grow bag mixture obtained at the outlet was weighed and the corresponding time was recorded using a stopwatch. Knowing the time required and weight of the mixture, the capacity was calculated as,

$$\text{Capacity, kg h}^{-1} = \frac{\text{Weight of the mixture obtained}}{\text{Time taken in one hour}}$$

Capacity was also calculated based on the number of bags filled per unit time. Three different sizes of bags were filled and the capacity for each size of bag in terms of number of bags was calculated. The time elapsed for replacing filled bags with empty ones was also noted. It was calculated as,

$$\text{Capacity} = \frac{\text{Number of bags filled}}{\text{Time taken, h}}$$

3.5.4 Energy consumption

It is the amount of electrical energy consumed by the machine for filling grow bags in one hour. A single phase energy meter with 1200 rpm, 230 v, 5 A and 50 Hz was used for the energy measurement. It was connected to the terminals of the machine and the number of revolutions were recorded for each type of bags. Electrical energy consumed was calculated using the equation,

$$\text{Energy consumed in kWh} = \frac{N}{K}$$

where, N = number of revolutions of the disc

K = 600, meter constant

3.5.5 Efficiency of the machine

Efficiency of the machine was the ratio of weights of materials filled in the bags to the weight of materials fed through the feeding chute. Efficiency was calculated at different moisture contents of the materials.

$$\text{Efficiency, \%} = \frac{Weight\ of\ materials\ filled}{Weight\ of\ materials\ added\ through\ the\ chute} \times 100\%$$

3.5.6 Types of grow bags

Three types of grow bags were selected for the performance evaluation of the developed machine. Small, medium and large type grow bags with size of 16 x 16 x 30, 20 x 20 x 35 and 24 x 24 x 40 cm respectively were used for filling. The material was LDPE poly plastic dual layer and had thickness of 150 microns, 600 gauge. Those bags were UV stabilized with outside white and inside black in colour.

3.6 FACTORS SELECTED FOR THE EXPERIMENT

The different factors selected for the experiment are given in Table 3.1. Performance of the grow bag filling machine were analyzed w.r.t the following selected factors.

Table 3.1 Levels of the factors selected for the experiment

Materials	Moisture content, %	Clearances, mm	Ratios (S:C:FYM)	Bag size
Soil	10	15	1:1:1	Small (16x16x30 cm)
Coir pith	15	20	1:0.5:1	Medium (20x20x35 cm)
Cow dung	20	25		Large (24x24x40 cm)
	25			
	30			

3.7 STATISTICAL ANALYSIS

The effect due to change in moisture content, clearance between the sieve and the blade, different ratios of grow bag mixtures were statistically analyzed for the mixture. Also, the performance of the machine was analyzed for different treatment combinations using SPSS software (Version 16.0) and the results are given in the Art 4.4.

3.8 COST ECONOMICS

The hourly cost of operation with the machine for filling different bags were calculated using the standard procedures and is given in Appendix XIV.

RESULTS AND DISCUSSION

CHAPTER IV

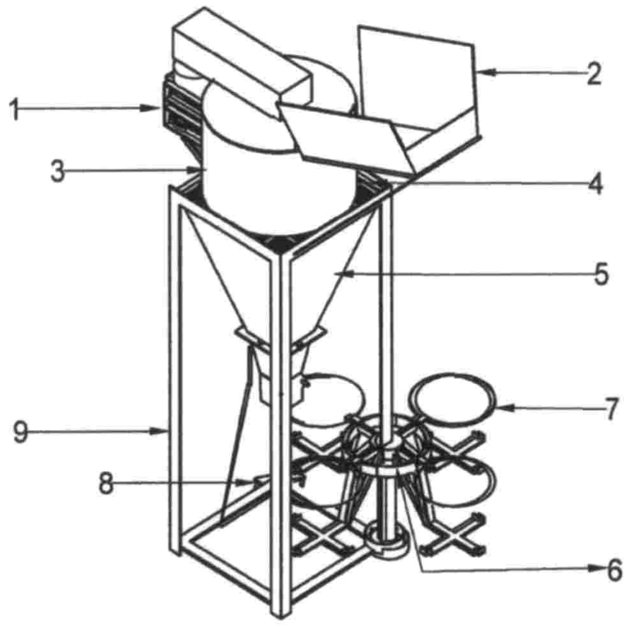
RESULTS AND DISCUSSION

This chapter includes the development of grow bag filling machine, the results of performance evaluation of the developed machine and its effectiveness in preparing the mixture. The different ratios of mixture, its moisture content and the machine parameters viz., size of the sieve, clearance between the blade and rotational speed of the blades were selected as the major factors influencing the performance of the machine. Accordingly, the bulk density, porosity, fineness modulus, electrical conductivity, pH and uniformity of the mixture were evaluated to ensure a good quality growing media for plants.

The overall performance of the machine was also evaluated w.r.t weight of bags filled, capacity of the machine, efficiency, time and energy consumption at two different proportions such as 1:1:1 and 1:0.5:1 (S:C:FYM). Also evaluation w.r.t different grow bag sizes of small, medium and large. The variations of performances were analysed at five moisture contents of 10, 15, 20, 25 and 30 percent and at three clearances of 15, 20, and 25 mm respectively.

4.1 DEVELOPMENT OF GROW BAG FILLING MACHINE

A grow bag filling machine for filling grow bags was developed with the modification of KAU manure pulverizer. The following components viz., a bottom hopper to collect the mixture, a valve to control filling, a pedal for operating the valve, grow bag holders and a rotating grow bag holding stand were developed and attached to the KAU manure pulverizer to facilitate simultaneous filling of grow bags along with the pulverization. This power operated continuous type grow bag filling machine is capable of mixing, pulverizing, sieving, and filling of potting mixture materials in different sizes of grow bags.



Parts:

1. Electric motor
2. Feeding chute
3. Pulverizing drum
4. Sieve
5. Bottom collecting hopper
6. Grow bag holder stand
7. Grow bag holder
8. Pedal
9. Main stand

Fig. 4.1 Grow bag filling machine

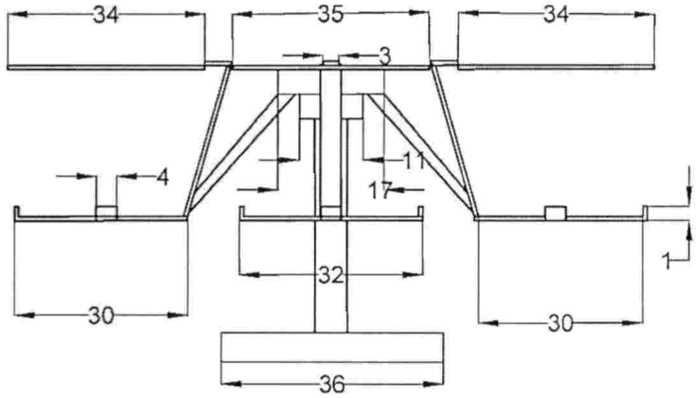
Plate 4.1 Grow bag filling machine

4.1.1 Collecting hopper

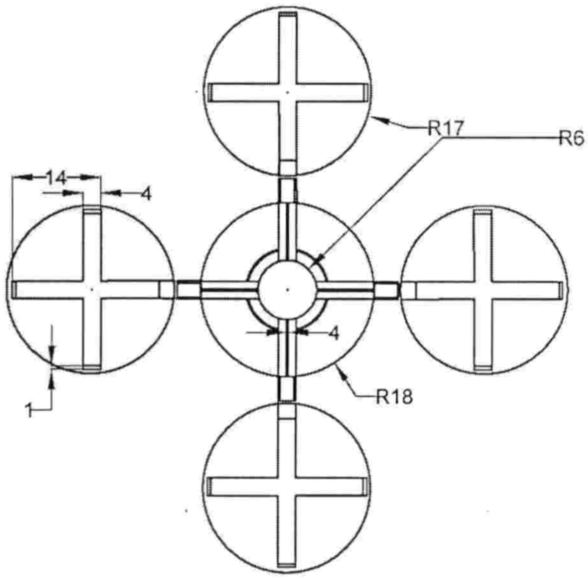
A hopper was placed vertically below the sieve to collect the powdered media. It was bolted to the main frame and was made of GI sheet of 1.2 mm thick. It was inclined to the horizontal at an angle of 70° and had a length of 490 mm. At the bottom of collecting hopper, another small hopper was bolted to it and had a length of 280 mm. A pedal operated square shape valve was inserted into the small hopper to facilitate metered discharge of the potting media. As and when it is allowed to open a metered quantity of the mixture was discharged into the grow bags placed below it.

4.1.2 Grow bag holder

A grow bag holder was separately made and attached to one of the leg of supporting stand (Fig. 4.2). A roller bearing at the top and one ball bearing at the bottom facilitated the rotation of holder within the leg of the stand. Four bags were placed at a time. Large grow bag holders of φ 290 mm and height 215 mm was made and welded to the rotating stand. Four medium bag holders of φ 256 mm and height 215 mm and four smaller bag holders of φ 185 mm and height 190 mm were made for placing medium and small bags respectively (Fig.4.3). To enhance fast and easy replacement of grow bags, buckets with grow bags of same size were used and these buckets were placed in the grow bag holders. Ordinary plastic buckets were used for the purpose.



(a)



(b)

Fig.4.2 Elevation (a) and plan (b) of grow bag holder stand

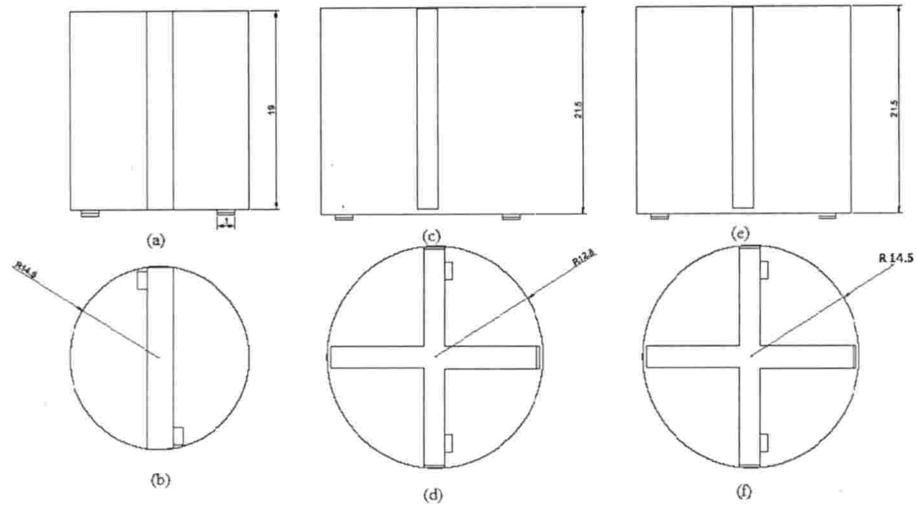


Fig.4.3 Elevation (a) and plan (b) of small bag holder, elevation (b) and plan (c) of medium bag holder and elevation (e) and plan (f) of large bag holder

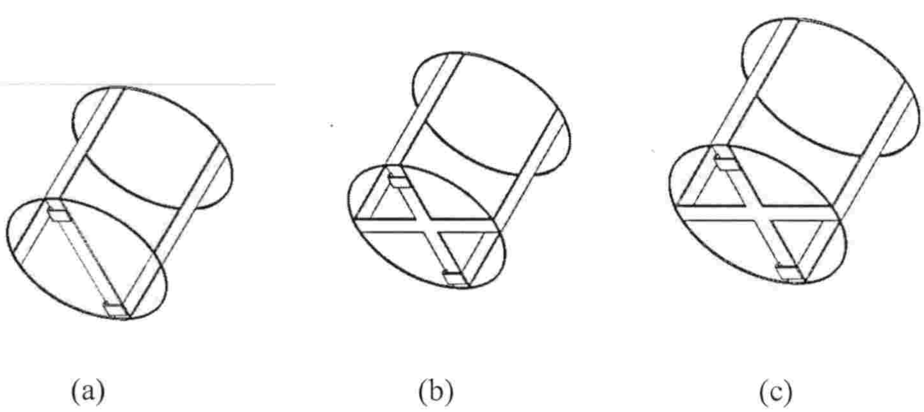


Fig.4.4. Isometric view of small (a) and medium (b) and large bag holders

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4.1.3 Feeding stand

A stand of height 680 mm was fabricated for feeding materials into the pulverized drum. Another small step with a height of 305 mm was welded to it. Rectangular shaped steps had the dimensions of 480 mm x 315 mm for top and 480 mm x 220 mm for bottom respectively.

4.1.4 Main stand

The entire grow bag filling units viz. electric motor, mixing and pulverizing drum, driving members, sieve, hoppers, valves, pedal and bag holders were mounted on stand with four M.S angles of size 50 x 50 x 6 mm and with a height of 750 mm.

4.2 WORKING OF GROW BAG FILLING MACHINE

The machine is a gender friendly unit and can be operated by any unskilled labourers. Two operators are required for its working. One person can feed and guide the material into the main pulverising cum mixing drum in standing posture while the collection of filled bags and its replacement with empty bags is controlled by second person in sitting posture.

The soil and other potting materials should not be wet and reasonably dry for better handling and pulverization. Soil, coir pith and FYM (cow dung) were fed in to the pulverizing cum mixing drum in the specified quantities. Feed rate was controlled by a lid provided at the feeding chute. Materials were pulverized and mixed due to rotations of the blade which caused the cutting and shearing actions and got pulverized in the clearance between the blade and the sieve. The grow bag mixture was discharged through the sieve and collected in the bottom hopper. A pedal operated valve was inserted into the small hopper to facilitate metered discharge of the potting media. As and when it is allowed to open a metered quantity of the mixture was discharged into the grow bags placed below it.

4.2 DETERMINATION OF PROPERTIES OF RAW MATERIALS

Soil, coir pith and cow dung were selected as the raw materials for the preparation of grow bag filling mixture. The raw materials were selected at dried and powdered conditions. Different properties of these raw materials such as moisture content, bulk density, porosity, fineness modulus and pH were found out using standard test procedures and are given in Table 4.2.

Table 4.2 Properties of raw materials of grow bag filling mixture

Sl. No.	Raw materials	Moisture content (percent)	Bulk density ($g.cm^{-3}$)	Porosity (percent)	Fineness modulus	pH
1	Soil	5.55	1.20	51.8	4.35	5.8
2	Coir pith	10.70	0.13	50.76	5.41	5.3
3	Cow dung	10.83	0.31	66.26	5.90	7.4

Grow bag filling machine was tested using the mixture at five moisture contents. Water was added in required quantities to make the moisture content of the mixture at 10, 15, 20, 25 and 30 percent respectively. The three raw materials with same moisture were mixed and fed into the machine at a time.

4.3 DETERMINATION OF MACHINE PARAMETERS

The important machine parameters that affect the machine performance include sieve size, clearance between the sieve and the blade and rotational speed of the blade. These parameters were determined using standard methods and were explained in the Art.3.5

4.3.1 Sieve size

The performance testing was conducted using the 10 mm sieve.

4.3.2 Clearance between sieve and blade

Clearances were changed to 15, 20 and 25 mm respectively w.r.t different grow bag mixtures at different moisture contents.

4.3.3 Rotational speed

The machine was tested at 1440 rpm at all mixture combinations. A tachometer was used to measure the rotational speed of the blades to ensure the constant speed at all operating conditions.

4.3 DETERMINATION OF GROW BAG MIXTURE PARAMETERS

Various mixture parameters such as water holding capacity, bulk density, porosity, fineness modulus, angle of repose, electrical conductivity and pH were measured at different physical conditions of the raw materials and machine parameters. The effect due to five moisture contents, three clearances between sieve and blade and two different proportions of mixture on the above mentioned parameters were found out.

Soil (S), coir pith (C) and cow dung (FYM) were mixed used in two different proportions by volume for the preparation of grow bag mixtures viz S: C: FYM = 1:1:1 and S: C: FYM = 1:0.5:1.

4.3.2 Water holding capacity

A good planting mixture should have ingredients that help it retain moisture. Coir pith serves the purpose of holding moisture and reduces the number of irrigations. Water holding capacities of different grow bag mixtures obtained are shown in Fig. 4.5. It was observed that the values varied between 155.54 and 166.90 percent at the ratio of 1:1:1 and 117.08 and 124.89 percent at 1:0.5:1.

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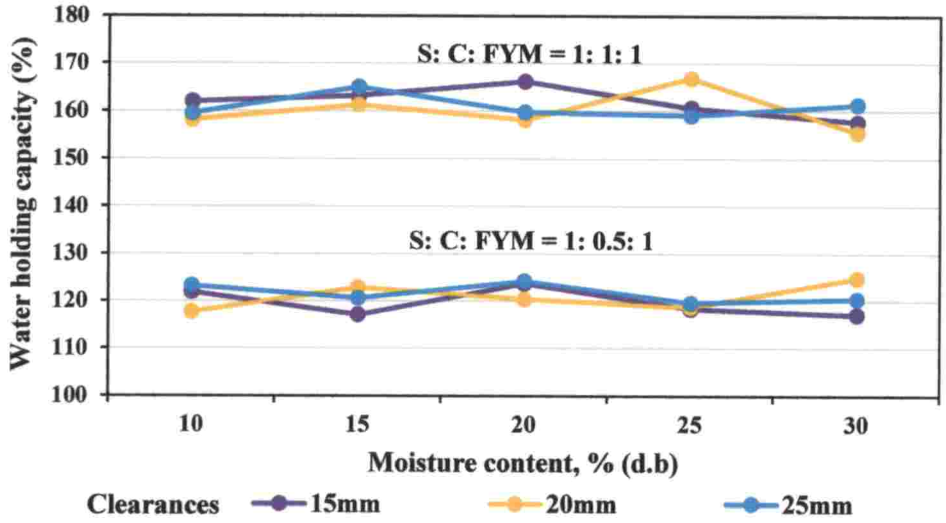

Fig. 4.5 Water holding capacities of mixtures at S: C: FYM 1:1:1 and 1:0.5:1

Water holding capacity decreased when the volume of coir pith in the ratio is reduced to half. The values of water holding capacity with various moisture contents and clearances were found out and were statistically analysed and are for presented in Appendix I and II. It is clear that the moisture of mixtures and the clearances adjusted between the sieve and the blades had no much effect on the water holding capacity for both the proportion of mixture and it is only changed by the difference in proportion of mix.

4.3.3 Bulk density

Bulk density is an important factor in grow bag cultivations. Mixtures with very low bulk densities are unstable in windy conditions and mixtures with high bulk densities can cause decreased root penetration. So it is desirable to have an optimum bulk density for grow bag mixtures to facilitate proper anchorage to the plants grown. The bulk densities of grow bag mixtures with different proportions, moisture contents and clearances are shown in Fig. 4.6 and were statistically analysed and are given in Appendix III and IV. The values of bulk densities varied between 0.462 and 0.572 $g.cm^{-3}$ at the ratio of 1:1:1 and 0.542 and 0.631 $g.cm^{-3}$ at the ratio of 1:0.5:1.

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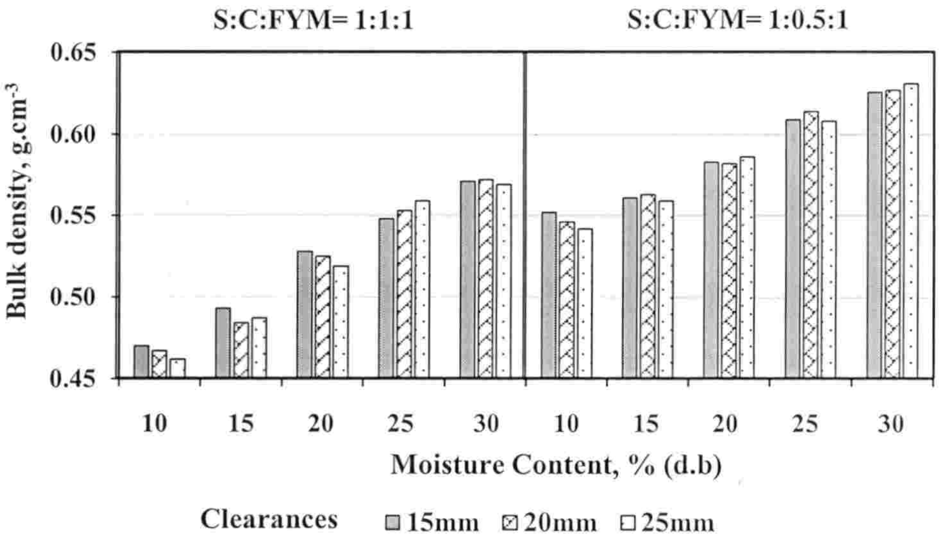

Fig. 4.6 Bulk densities of grow bag mixtures at S: C: FYM 1:1:1 and 1:0.5:1

It is observed that the bulk density had shown an increasing trend with the increase in moisture content for both the proportions. Effect due to clearance on bulk density was negligible. Bulk density was slightly higher for the ratio 1:0.5:1 since there was 50 percent reduction in the volume of coir pith. This may be due to the lower density of the coir pith. Hence it is assumed that the increased bulk density was due to the comparable high volume of soil and cow dung in the second mix. Hence the mixture with bulk density around 0.4 to 0.5 $g.cm^{-3}$ can be considered as optimum for a potting mixture. (Goh and Haynes, 1977).

4.3.4 Porosity

Porosity is another factor that influences the root growth of plants grown in bags and containers. Media should provide proper aeration and drainage. It was found out from the calculated values of bulk densities and particle densities. Particle densities of 1.40 $g.cm^{-3}$ and 1.50 $g.cm^{-3}$ were obtained as average values for the first and second proportions of mixture respectively. The values of porosity of mixtures for two ratios, five moisture contents and three clearances were found out and were statistically analyzed and are given in Appendix V and VI. In the 1:1:1 ratio, porosity varied from 59.14 to 67.00 percent and 57.93 to 63.87 percent for the

1:0.5:1 ratio. The change of values of porosity with different moisture content and clearances at two mixture ratios are shown in Fig. 4.7.

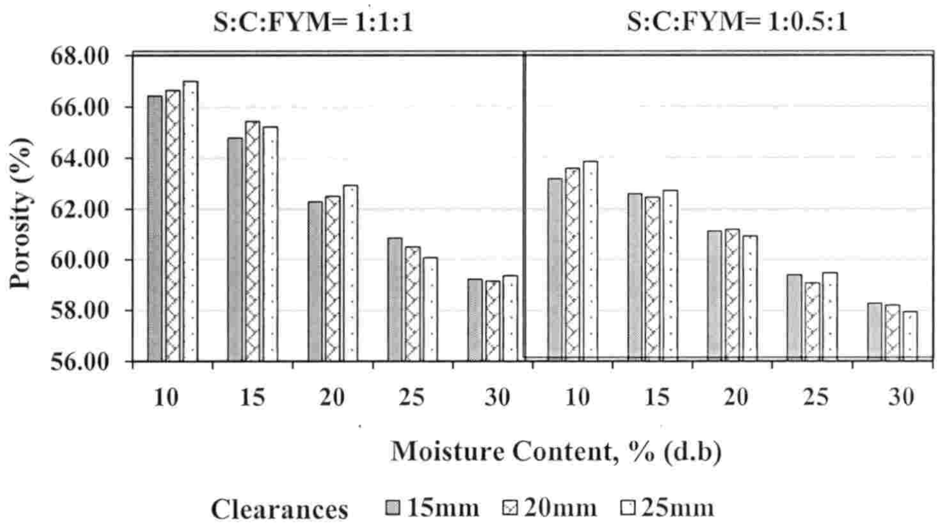

Fig. 4.7 Porosities of grow bag mixtures at S: C: FYM 1:1:1 and 1:0.5:1

It is clear that the porosity of grow bag mixtures decreased with the increase in moisture content. This is due to the increase in bulk density with moisture content. The ratio 1:1:1 had higher values of porosity for the respective moisture contents and clearances. It is due to the higher percentage of coir pith in the ratio whose porosity was higher when compared to other raw materials. Effect due to clearance on porosity was also negligible.

4.3.5 Fineness modulus

Fineness modulus of mixtures at two ratios, for five moisture contents and for three clearances were determined by sieve analysis and corresponding values are given in Appendix IV. It varied from 4.89 to 6.18 at the ratio of 1:1:1and 5.11 to 6.42 at the ratio of 1:0.5:1. Variation of fineness modulus with moisture content and clearances for two ratios were statistically analysed and given in Appendix VII and VIII and the corresponding values are shown in the Fig 4.8.

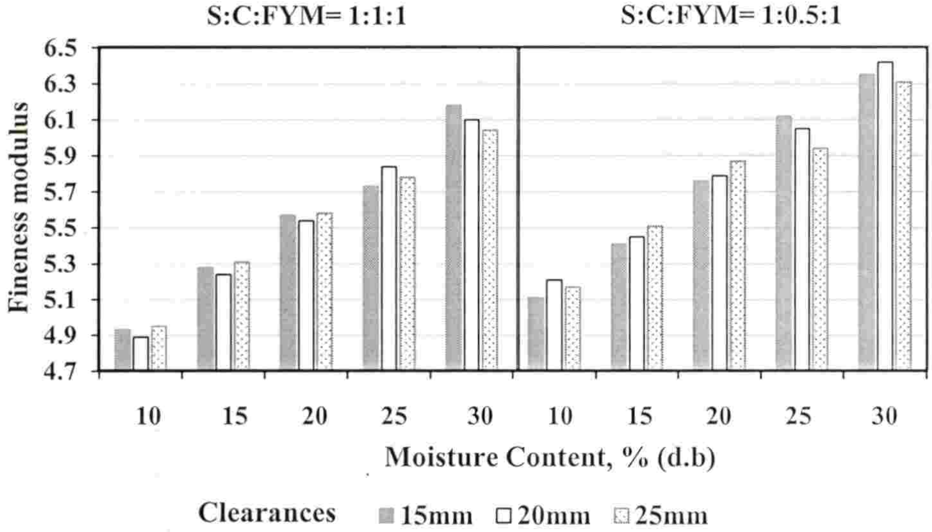

Fig. 4.8 Fineness modulus of grow bag mixtures at S: C: FYM 1:1:1 and 1:0.5:1

Fineness modulus increased with the increase in moisture content of mixture. More fine powder was obtained when the materials were dry. It may aid in easy intake of nutrients by the plants. Effect due to clearance on fineness was negligible. Fineness modulus is slightly higher for the ratio 1:0.5:1. It is due to the presence of high proportion of cow dung particles with larger fineness modulus value.

4.3.6 Angle of repose

Angle of repose plays an important role in the design of conveyors and hoppers. Angle of repose of mixture varied with the changes in moisture content and proportion of mixture. The effect due to change in moisture content, clearances and ratios of mixture were statistically analysed for angle of repose and are given in Appendix IX and X. It varied between 43.24° and 57.00° at the ratio of 1:1:1 and 35.66° and 49.56° at the ratio of 1:0.5:1.The variation of angle of repose with the above parameters are shown in Fig. 4.9.

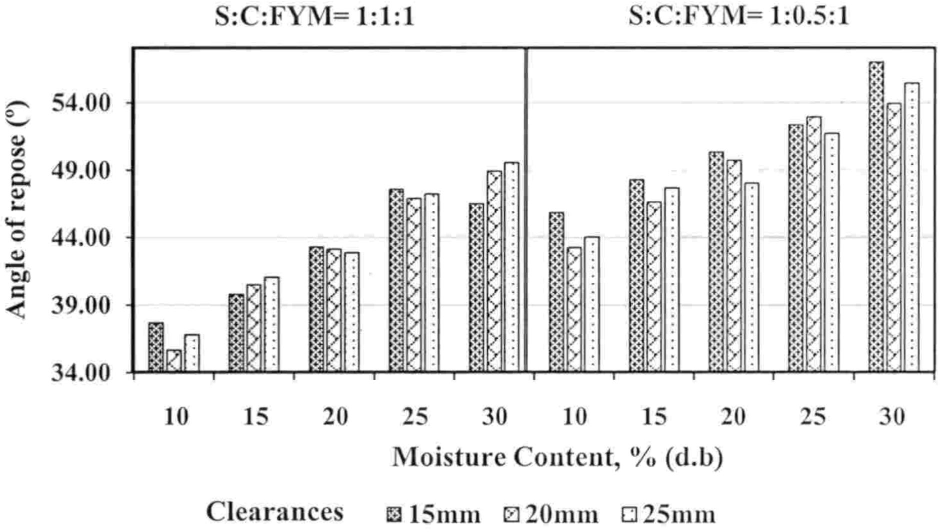

Fig. 4.9 Angle of repose of grow bag mixtures at S: C: FYM 1:1:1 and 1:0.5:1

The illustrations revealed that angle of repose of grow bag mixture increased with the increase in moisture content. Effect due to clearance on angle of repose was insignificant. Angle of repose attained higher values for the ratio 1:0.5:1 since the mixture obtained was finer and angle of repose increases with the decrease in particle size of powder (Carstensen and Chan, 1976).

4.3.7 pH

The pH of media is important as it influences various plant growth factors such as soil bacteria, nutrients availability, soil structure and toxic elements. The pH values of different grow bag mixtures for different moisture contents, clearances and ratios were statistically analysed and are given in Appendix XI and XII. It varied between 6.7 and 6.9 at the ratio of 1:1:1 and 6.8 and 7 at the ratio of 1:1:1. The variation of pH with the mentioned factors are shown in Fig. 4.10.

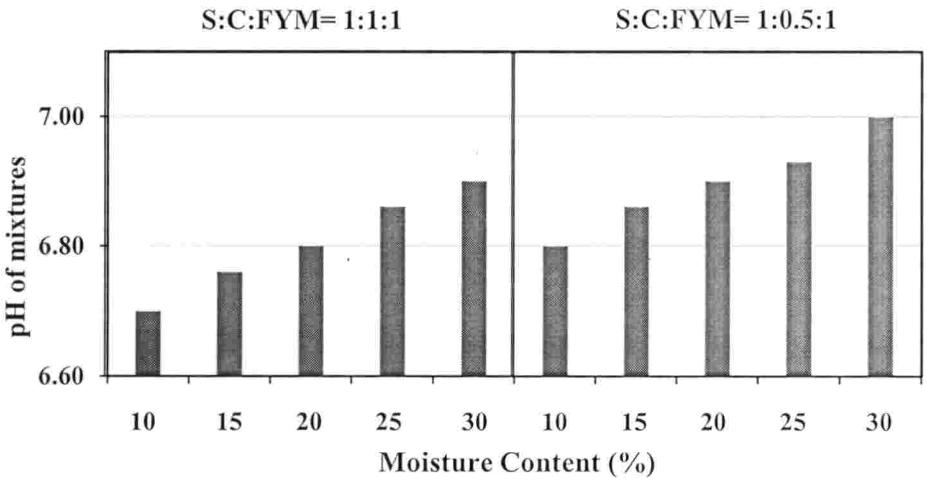

Fig. 4.10 pH of grow bag mixtures for S: C: FYM as 1:1:1 and as 1:0.5:1

It is observed that of pH increased with the increase in moisture content of mixture as concentration of the solution decreases. For a given ratio of mixture, at a particular moisture content, pH remained constant for all the clearances. Variation of clearances had no significance effect in pH values. The value of pH was found to be low at the ratio of 1:1:1. It is due to high volume of coir pith with acidic nature.

4.3.8 Electrical conductivity

Electrical conductivity is considered as an indication of the availability of nutrients in the growing mixture. It was measured for different moisture contents, ratios of mix and clearances and the corresponding values were statistically analysed and are presented in Appendix XIII and XIV. It varied from 1.99 to 2.71 $dS.m^{-1}$ at the ratio of 1:1:1 and 2.08 to 2.68 $dS.m^{-1}$ at the ratio of 1:0.5:1. The change of electrical conductivity with different moisture contents, clearances and ratios are shown in Fig. 4.11 and Fig. 4.12.

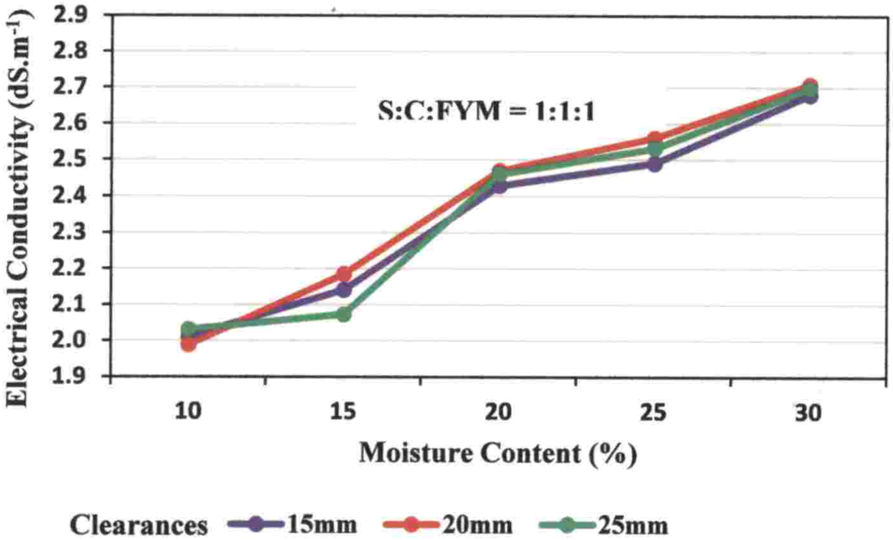

Fig. 4.11 Electrical conductivity of grow bag mixtures at the ratio of 1:1:1.

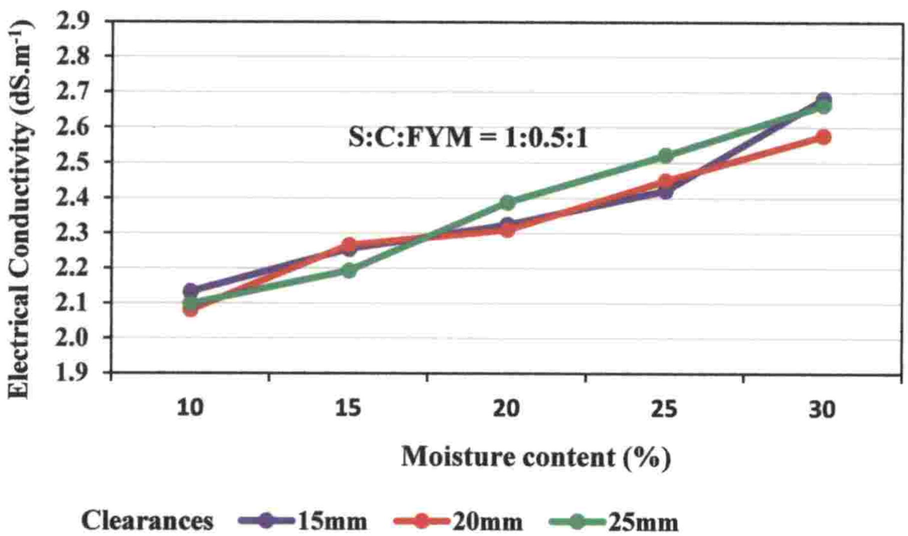

Fig. 4.12 Electrical conductivity of grow bag mixtures at the ratio of 1:0.5:1.

The analysis revealed that the electrical conductivity of grow bag mixture is found to increase with the increase in moisture content. It is presumed that the more the moisture content, the more the cations present in the solution of the media. The effect of change in clearances were not significant for the two different mixes on electrical conductivity. It is evident that the effect due to moisture was significant on electrical conductivity.

4.3.9 Uniformity of mixture

The percentage deviation of bulk densities of the samples of top, middle and bottom with reference bulk density were found out. The variation of bulk density in different portions of a bag when compared to reference values were statistically analysed and are presented in Appendix XV and XVI. The corresponding values for uniformity deviation of mixtures for varying moisture contents w.r.t different clearances and mixture ratios are shown in Fig. 4.13 and Fig. 4.14

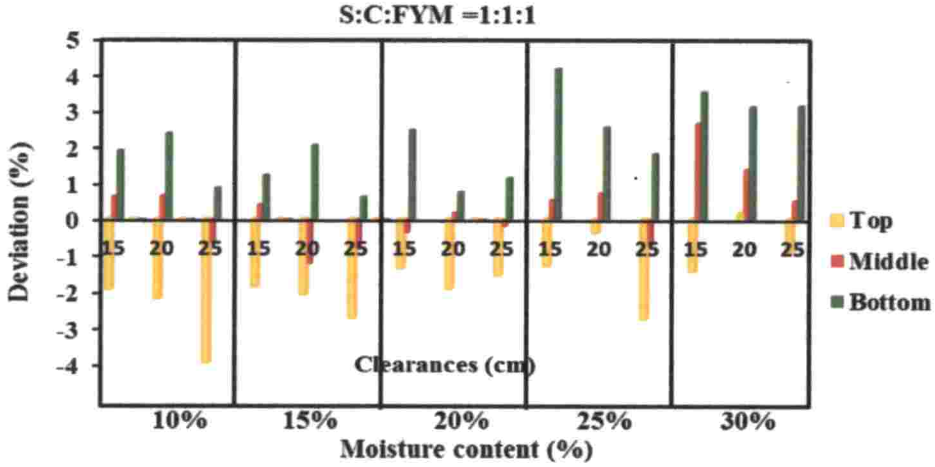

Fig. 4.13 Uniformity deviation of grow bag mixtures at S: C: FYM = 1:1:1.

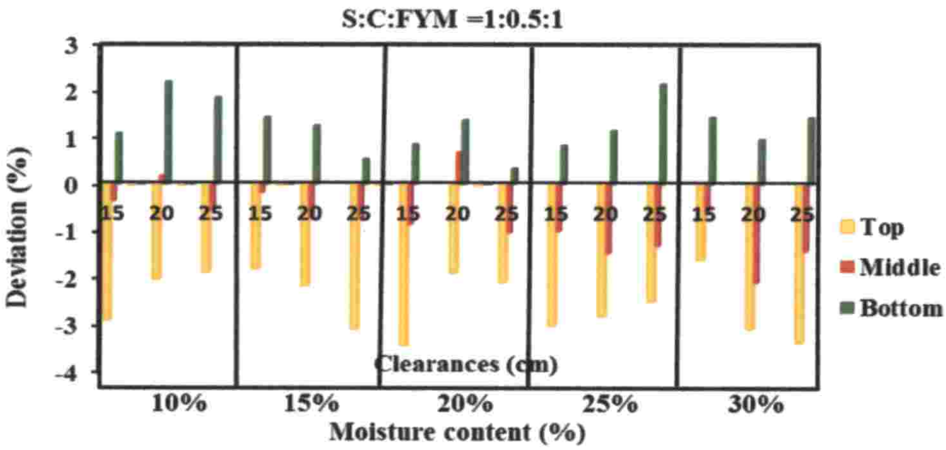

Fig. 4.14 Uniformity deviation of grow bag mixtures at S: C: FYM = 1:0.5:1.

From the Fig. 4.9 and Fig. 4.10, it is observed that, at both the ratios, percentage deviation of bulk density from the reference values were found within the limit. A maximum percentage deviation of 4.17 percent was recorded at the ratio 1:1:1 while it was 3.06 percent for the ratio 1:0.5:1. Change in moisture or clearance or ratio have no influence in the deviation of uniformity.

On other hand, analysis revealed that change of bulk density in different portions of bags was significant. Bulk density measured from the bottom portion of the bag recorded maximum value whereas minimum value recorded at the top. The deviations were found to be minimum at the centre portion and marked a small increase toward both ends. It may be due to the fact that finer soil particles settled faster under gravity at bottom. At the same time the overall deviations were found to be minimum throughout the bag. Hence, it is concluded that the grow bag mixture is filled uniformly by using the newly developed machine.

4.4 PERFORMANCE PARAMETERS

4.4.1 Weight of bags filled

Grow bags are usually filled to the three-fourth of its volume to have proper watering. Bags with less weights are preferred so as it facilitate easy transportation during filling and subsequent growing stages of the plant. Weight of grow bags filled is affected due to change in bulk densities which in turn due to the change in moisture content. The average weights of three types of filled bags viz small medium and large for varying moisture contents, mixing at different clearances and ratios were statistically analysed and are given in Appendix XVII and XVIII and the values are shown in Fig. 4.15, Fig. 4.16 and Fig. 4.17.

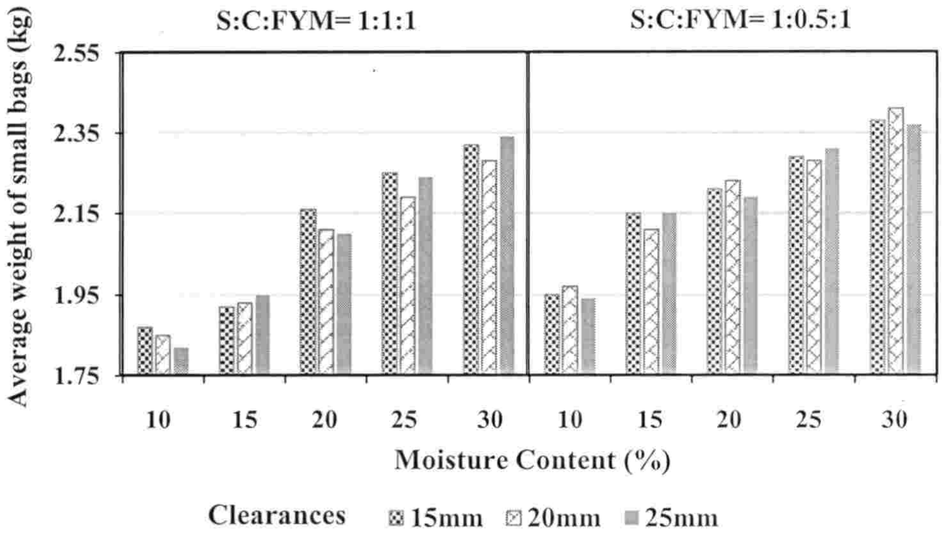

Fig. 4.15 Weight of small grow bags filled at different moisture contents.

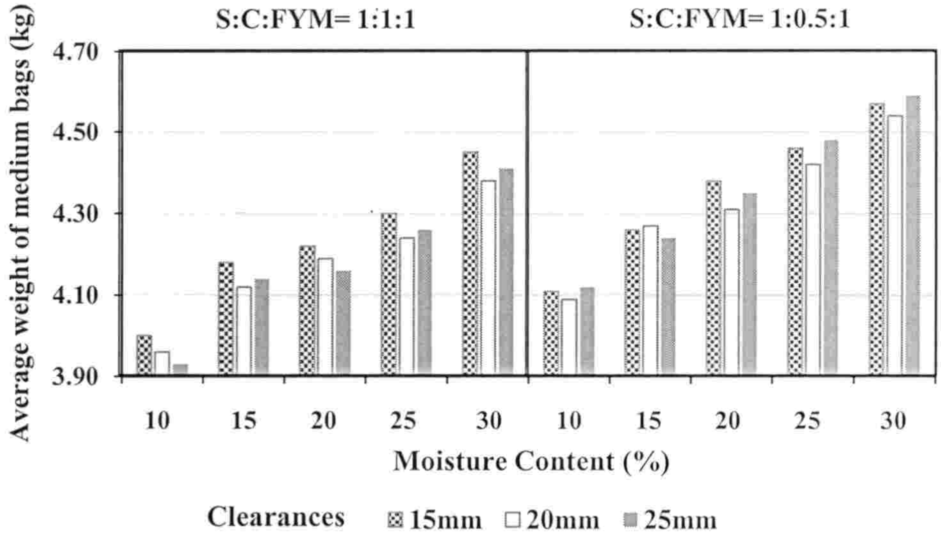

Fig. 4.16 Weight of medium grow bags filled at different moisture contents.

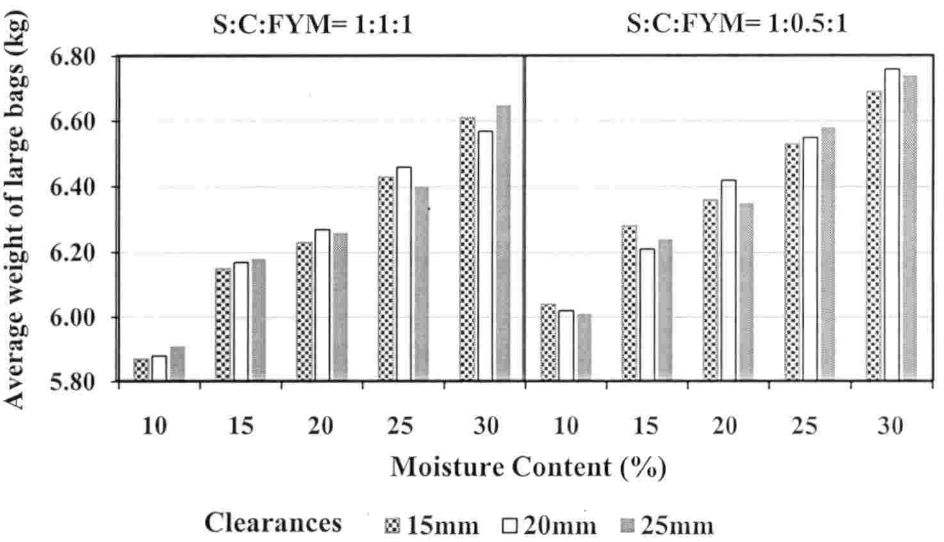

Fig. 4.17 Weight of large grow bags filled at different moisture contents.

The average weight of small bags were in the range of 1.82 to 2.34 kg at 1:1:1 ratio and 1.94 to 2.41 kg at 1:0.5:1 ratio. While, the average weights of medium grow bags varied between 3.93 and 4.45 kg and between 4.09 and 4.59 kg at 1:1:1 and 1:0.5:1 ratio respectively. The same trend was observed for large bags, i.e between 5.87 and 6.65 kg for 1:1:1 ratio of mix and between 6.01and 6.76 kg for 1:0.5:1 ratio.

From the Fig. 4.11, Fig. 4.12 and Fig. 4.13, it is clear that the weight of three types of grow bag mixtures increased with the increase in moisture content of the materials. No noticeable effect was observed for the change in clearances. It was also found that the weights were slightly greater for the ratio 1:0.5:1 compared to 1:1:1 ratio. It was due to the fact that coir pith with lesser density is in higher proportion at 1:0.5:1 ratio.

The results of analysis revealed that the mixture with ratio S: C: FYM as 1:1:1 at moisture levels of 10 and 15 percent were found to be significantly superior in case of weights of bags filled and marked as 'a', irrespective of bag size and change in clearance.

4.4.3. Time taken for filling grow bags

Time for filling the small, medium and large grow bags were different. It is an important parameter for calculating the performance of the developed machine. It has a direct impact on capacity of the machine. The grow bag holding stand of the machine consists of four bag holders. In order to work continuously using the machine, it was found out that total time taken for taken for placing four empty bags and removal of the four filled bags was 40 s. The effect due to change in moisture content, clearances and ratios on time for filling different bags were statistically analysed and are presented in Appendix XIX and XX. The corresponding values of time for filling different bags are shown in Fig. 4.18, Fig. 4.19 and Fig. 4.20.

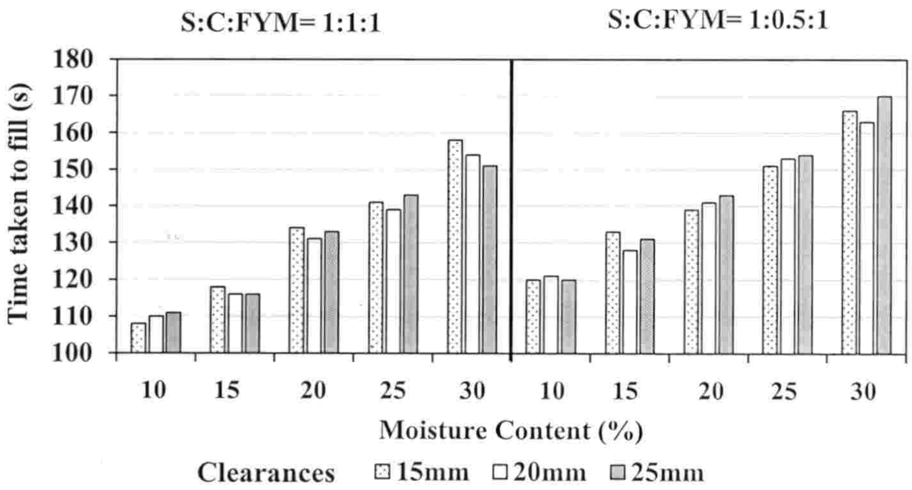

Fig. 4.18 Total time taken to place, fill and to remove four small grow bags at different ratios.

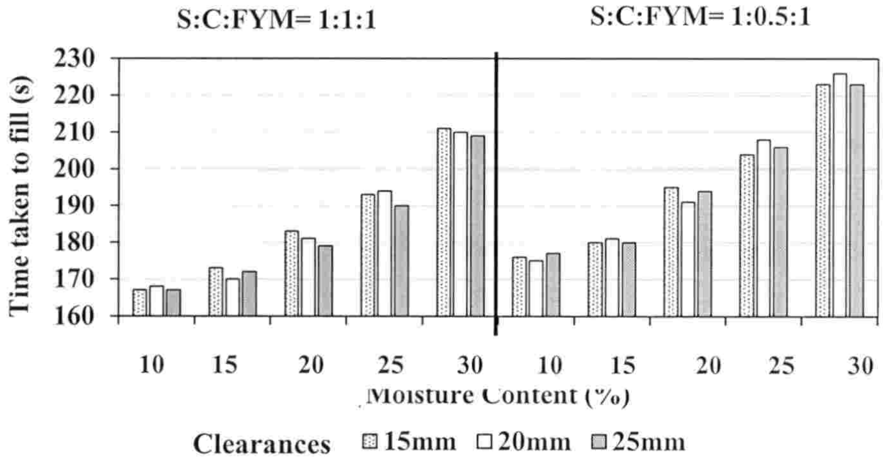

Fig. 4.19 Total time taken to place, fill and to remove four medium grow bags at different ratios.

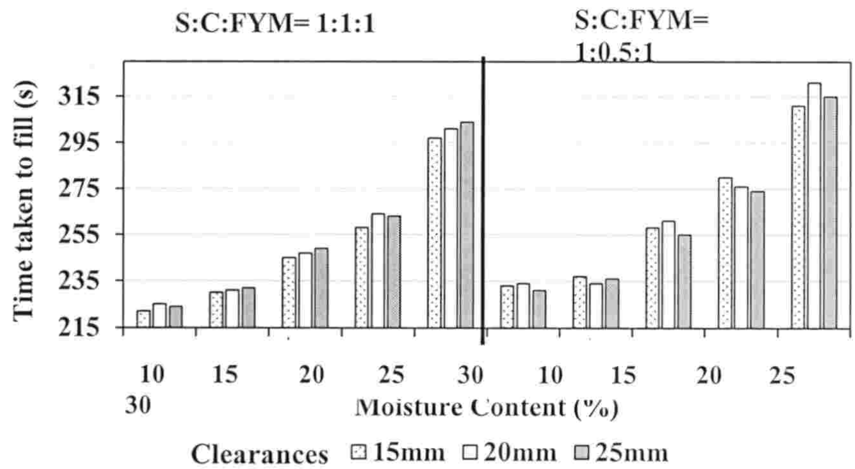

Fig. 4.20 Total time taken to place, fill and to remove four large grow bags at different ratios.

Time of filling increased with the increase in moisture content of the materials for all types of bags. More time was recorded for the filling of mixture with proportion S: C: FYM as 1:0.5:1 irrespective of bag size. It may be due to the increased amount of dried cow dung, which was harder and larger in size. The time taken for pulverizing the dried cow dung is more compared to other raw materials. Time of filling the grow bags w.r.t the change in clearance was negligible.

The results of analysis revealed that the mixture with ratio S: C: FYM as 1:1:1 at moisture levels of 10 and 15 percent were found to be significantly superior in case of time consumption and marked as 'a', irrespective of bag size and change in clearance.

4.4.4 Capacity of the machine

Capacity of the grow bag filling machine was calculated as the total quantity of materials filled in grow bags in an hour at its filling efficiency. It is considered as an important parameter for the performance evaluation of the machine. It differed for varying sizes of grow bags. Capacity of the machine varied between 211 and 259 $kg.h^{-1}$ for small bags, 300 and 355 $kg.h^{-1}$ for medium bags and 314 and 391 $kg.h^{-1}$ for large bags, at the ratio of 1:1:1. At 1:0.5:1 ratio, it varied between 201 and 247 $kg.h^{-1}$ for small bags, 289 and 345 $kg.h^{-1}$ for medium bags and 303 and 389 $kg.h^{-1}$ for large bags. Capacity of the machine at different moisture contents, clearances, ratio of mix and types of bags were statistically analysed and are given in Appendix XXI and XXII. The corresponding values of capacity are shown in Fig. 4.21, Fig. 4.22 and Fig. 4.23.

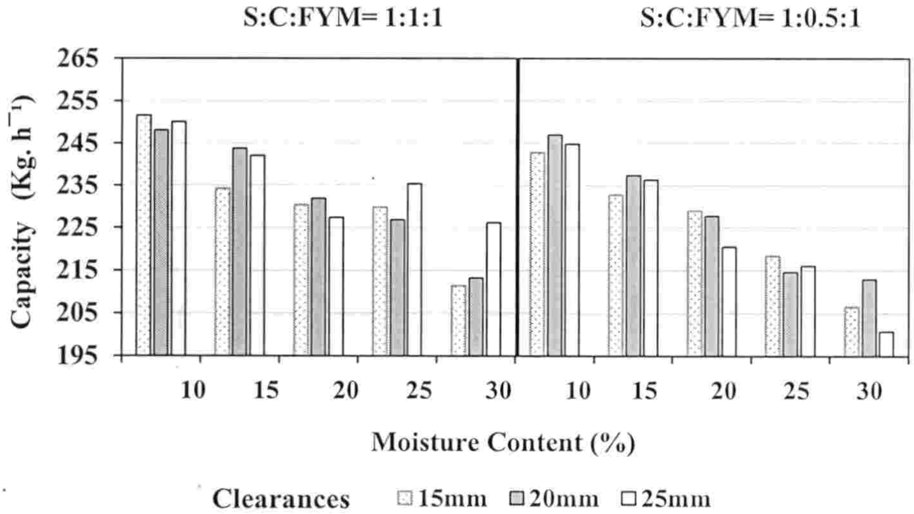

Fig. 4.21 Capacity of machine to fill small grow bags

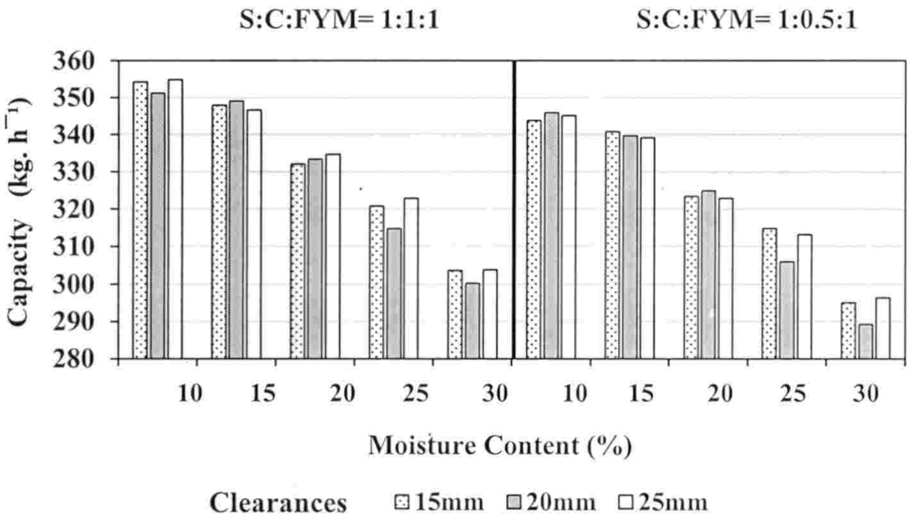

Fig. 4.22 Capacity of machine to fill medium grow bags

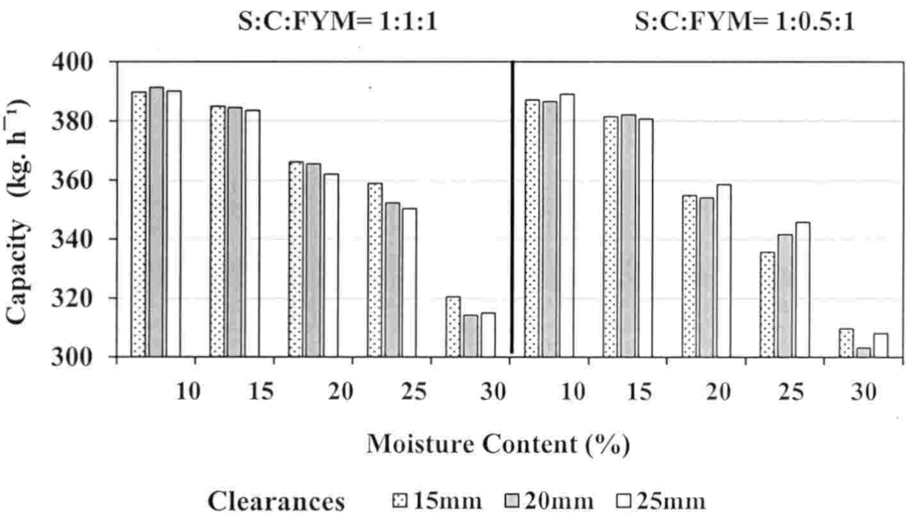

Fig. 4.23 Capacity of machine to fill large grow bags

Capacity decreased with the increase in moisture content of the materials. It is due to the higher time consumption. Time consumption increased with the increase in moisture content. The effect due to clearance on capacity was not significant. While considering the two proportion of mix, capacity was found to be larger at the ratio 1: 1: 1 for all types of grow bags. It is due to less time of filling at the ratio 1:1:1. The mixture with ratio S: C: FYM as 1:1:1 at moisture levels of 10 and 15 percent were found to be significantly superior for capacity values determined and marked as 'a', irrespective of bag size and change in clearance.

Capacity of the machine is also calculated based on the number of grow bags filled in one hour. More time of filling was recorded for large grow bags followed by medium and small bags. The number of bags filled in an hour varied in the range 91 to 131, 68 to 86 and 47 to 65 for small, medium and large grow bags respectively at the ratio of 1:1:1. Similarly it is observed that 85 to 120 small bags, 64 to 82 medium bags and 45 to 62 larger bags were filled at the ratio of 1:0.5:1. The effect due to moisture content, clearance, ratio of mixture and size of bags on number of bags filled were statically analysed and is given in Appendix XXIII and XXIV. The corresponding values of capacity in terms of number of bags filled are shown in Fig. 4.24, Fig. 4.25, and Fig. 4.26.

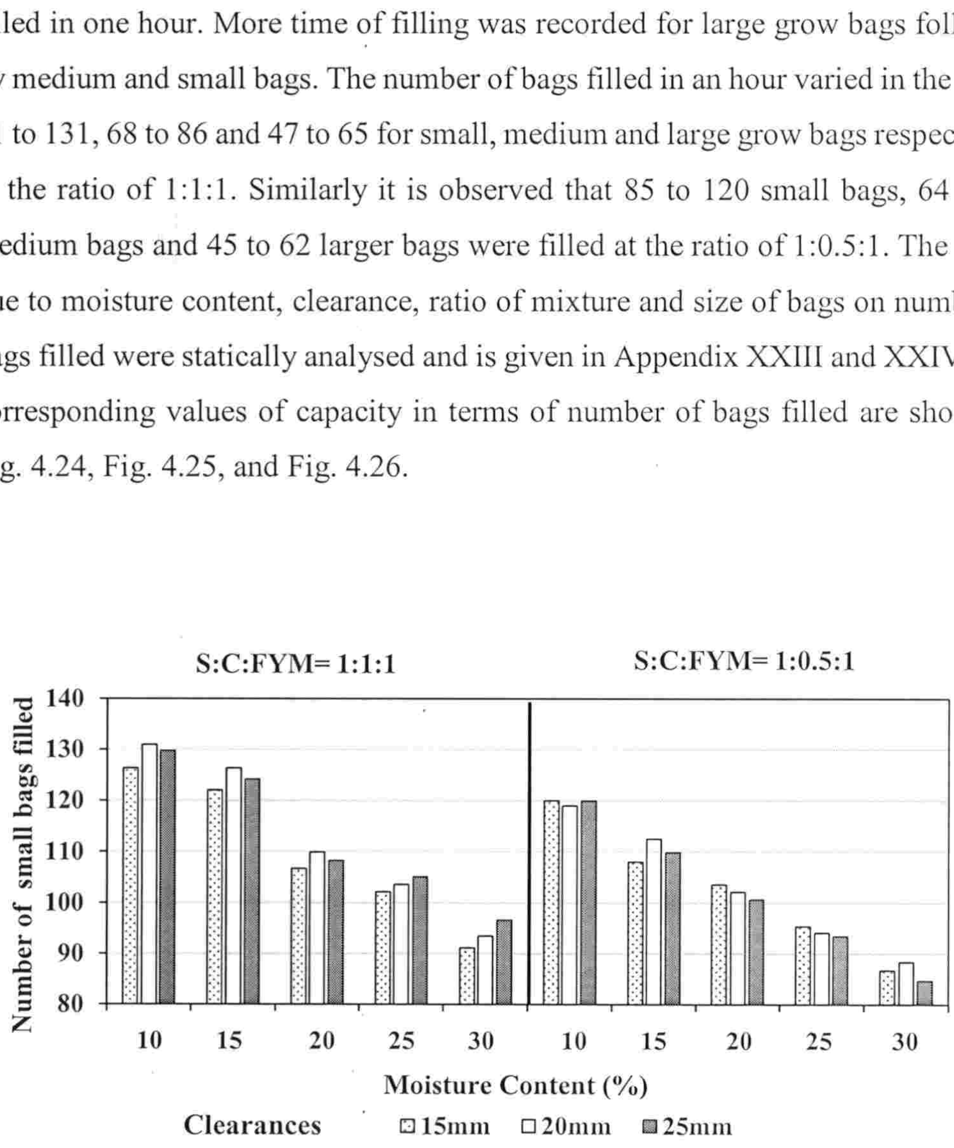

Fig. 4.24 Number of small bags filled in one hour

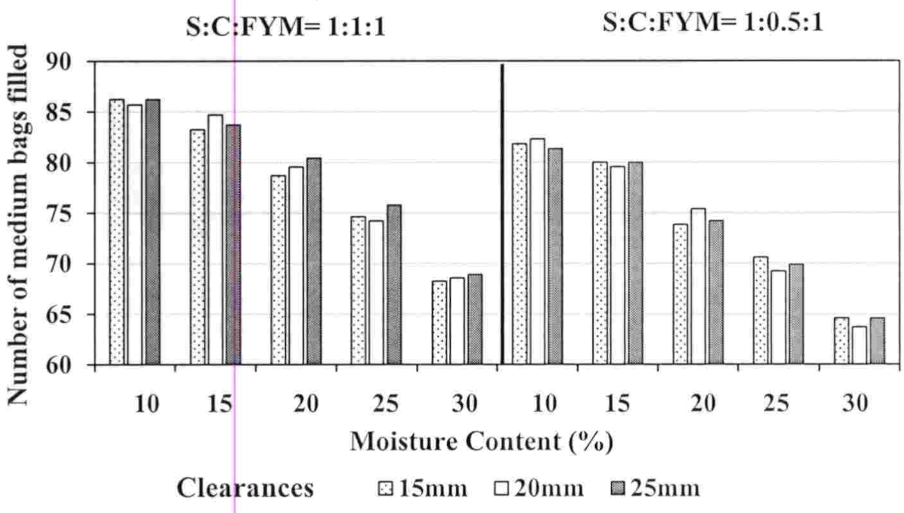

Fig. 4.25 Number of medium bags filled in one hour

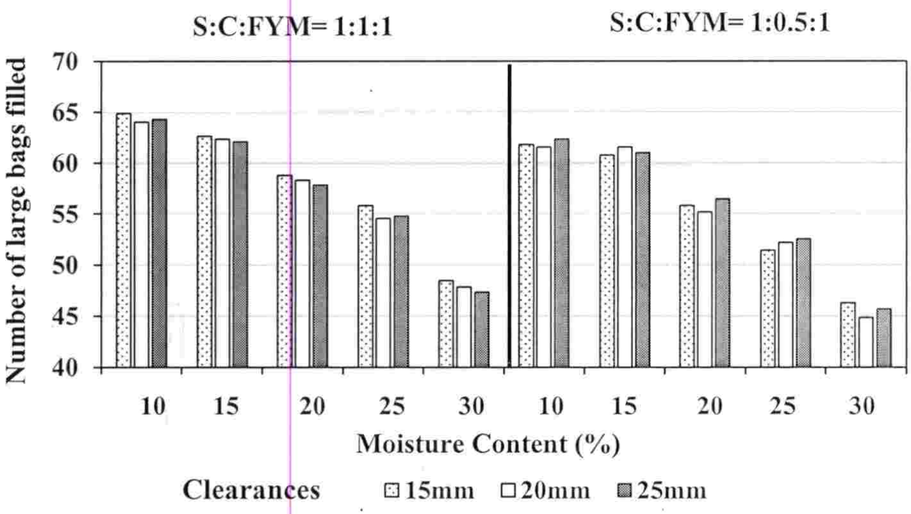

Fig. 4.26 Number of large bags filled in one hour

More number of small sized grow bags were filled in an hour compared to the other two bags. Number of bags filled decreased with the increase in moisture content of the materials irrespective of bag size. It is due to the increased time of filling. The effect due to clearance on number of bags filled was negligible. Number of bags filled was found to be larger at 1: 1: 1 ratio as less time was consumed for filling bags when compared with the other proportion. Proportion of cow dung was larger in 1:0.5:1 ratio and consumed more time for its pulverization.

The mixture with ratio S: C: FYM as 1:1:1 at moisture levels of 10 and 15 percent were found to be significantly superior and marked as 'a', irrespective of bag size and change in clearance.

4.4.5 Energy consumption of machine for filling different grow bags

The electrical energy consumed for filling four grow bags was calculated using an energy meter. The number of rotations of discs were recorded and energy consumption for all types of bags were determined. Energy consumed varied between 0.048 and 0.081 kWh for four small sized grow bags, 0.087 and 0.117 kWh for medium sized grow bags and 0.124 and 0.180 kWh for large sized grow bags, at 1:1:1 ratio. For the ratio 1:0.5:1, it varied between 0.055 to 0.085 kWh, 0.092 to 0.127 kWh and 0.131 to 0.192 kWh for four small, medium and large sized grow bags respectively. Energy consumption of filling various grow bags, at different moisture content, clearances and ratios were statically analysed and are given in Appendix XXV and XXVI. The corresponding values of energy consumption are shown in Fig. 4.27, Fig. 4.28 and Fig.4.29.

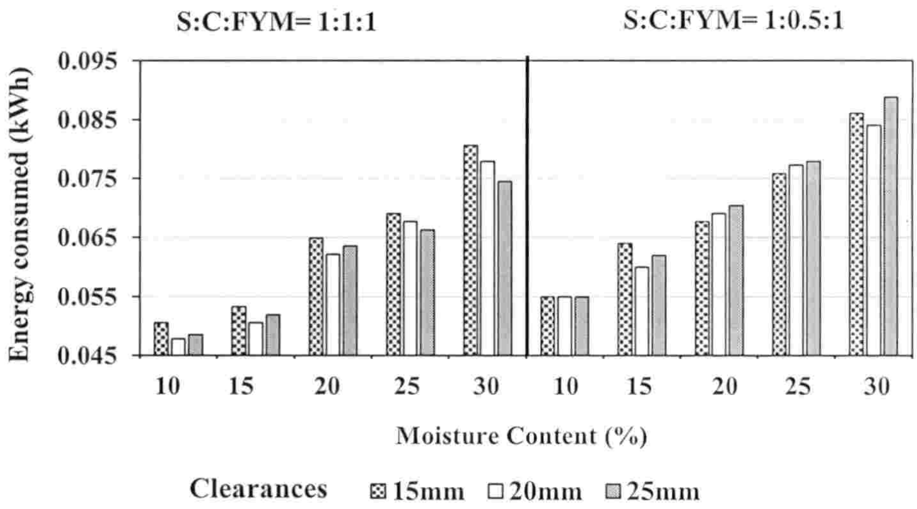

Fig. 4.27 Energy consumption for filling four small grow bags.

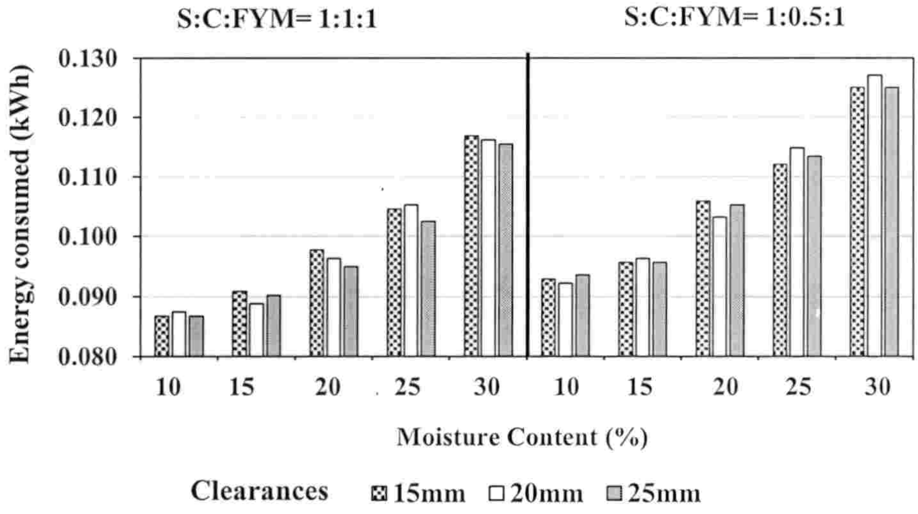

Fig. 4.28 Energy consumption for filling four medium grow bags

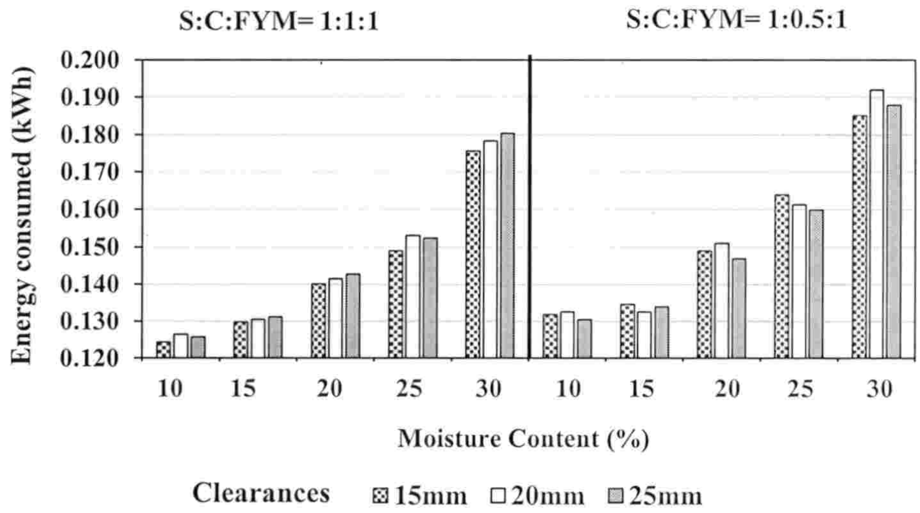

Fig. 4.29 Energy consumption for filling four large grow bags

From the analysis, it is concluded that the energy consumption increased as the moisture increased, for all the three types of bags selected. It was because more time and energy was required to pulverize materials of high moisture. As the quantity of mixture filled in the large bag is comparatively higher, more energy was consumed for its filling, followed by medium and small grow bags. The variation

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due to the clearance was observed minimum. More energy was consumed at 1:0.5:1 ratio as more time was consumed for the pulverization of dried cow dung. The mixture with ratio S: C: FYM as 1:1:1 at moisture levels of 10 and 15 percent were found to be significantly superior in case of energy consumption and marked as 'a', irrespective of bag size and change in clearance.

4.4.5 Efficiency of the machine

Efficiency of the machine is calculated as the ratio of amount of materials filled in the bags to the amount of materials fed through the chute. The capacity of the machine was found to be 500 $kg.h^{-1}$ when no bags were placed. Effect due to change in ratio of mixtures and change in clearance were negligible. Efficiency first increased and then decreased with the increase in moisture content. The values of efficiency for different moisture content are given in Table 4.2.

Table 4.3 Efficiency of grow bag filling machine for different moisture content

Moisture content, %	Efficiency, %
10	96.50
15	97.70
20	95.38
25	94.61
30	92.69

Material loss occurred at low moisture content in the form of dust. Maximum efficiency of 97.70 was found for 15 percent moisture content of materials. On further increase in moisture content, materials became adhesive and got clogged inside the drum and in the sieve. Therefore, 15 percent moisture content is considered as optimum for filling grow bags using the machine.

4.5 COST ECONOMICS.

The cost of grow bag filling machine is Rs.49500. The hourly cost of operation for the machine is calculated as Rs.357. The details of the cost analysis is given in Appendix XXVI.

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSIONS

Now a days, grow bag cultivation is getting wide acceptance in the state due to urbanisation and to produce good quality vegetables and floricultural production in short time and space. Fragmentation of agricultural lands and fear of use of harmful chemicals to increase production have also contributed significantly to the popularity of grow bag cultivation. The establishment of seedlings in the grow bag results better control of pest and disease which results an assured crop yield.

The filling of the mixture in grow bags is carried out unscientifically by manual method in almost all nurseries. Labourers are engaged for collecting, pulverising, mixing and filling the ingredients in the grow bag and are carried out in bending posture of the labourers. More energy and time are spent and hence it is a tedious and tiresome work. The development of a suitable machine for preparation and filling of potting mixture in grow bags of all sizes is the real need especially for homestead vegetable cultivation and for commercial nursery. Hence, a machine for filling potting mixture in grow bag was developed for filling grow bag of different size.

The main objectives of this research included the study of soil-mixture and machine parameters for grow bag filling, development of potting mixture filling machine for filling grow bags, the testing and optimization of the performance of the developed machine and the calculation of economics of the machine.

The KAU manure pulverizer was modified in such a way to accomplish it as a grow bag filling machine. The developed machine consisted of the following parts viz., electric motor, feeding chute, pulverizing drum, sieve, collecting hopper, grow bag holding stand, bag holders, pedal, supporting stand. Soil, coir pith and cow dung were the raw materials used for the preparation of grow bag mixture. Materials were pulverized and mixed due to rotations of the blade which caused the cutting and shearing actions and pulverized in the clearance between the blade and the sieve. The grow bag mixture was discharged through the sieve and got collected in the bottom hopper. A pedal operated valve was inserted into the small hopper to facilitate metered discharge of the potting media. As and when it is allowed to open a metered quantity of the mixture was discharged into the grow bags placed below it.

Different properties of raw materials such as moisture content, bulk density, porosity, fineness modulus and pH were found out. The properties such as water holding capacity, bulk density, porosity, fineness modulus, angle of repose, electrical conductivity and pH were measured for the evaluation of grow bag mixture. Various machine parameters such as speed of the machine, clearance between the sieve and the blade and the size of the sieve were considered for testing. The overall performance of the machine were also evaluated w.r.t weight of bags filled, capacity of the machine, efficiency, time and energy consumption

The testing of the machine was done at speed of 1440 rpm, 10 mm sieve and at clearances of 15, 20 and 25 mm. Moisture content of materials were changed to 10, 15, 20, 25 and 30 percent at two different proportions such as 1:1:1 and 1:0.5:1 (S:C:FYM). Three different size of bags viz., small, medium and large size was used. All the properties were statistically analysed to optimize the performance of the machine.

Water holding capacity varied between 155.54 and 166.90 percent at the ratio of 1:1:1 and 117.08 and 124.89 percent at 1:0.5:1. It decreased when the volume of coir pith in the ratio is reduced to half. It is clear that the moisture of mixtures and the clearances adjusted between the sieve and the blades had no much effect on the water holding capacity for both the proportion of mix.

The values of bulk densities varied between 0.462 and 0.572 g.cm^{-3} at the ratio of 1:1:1 and 0.542 and 0.631 g.cm^{-} at the ratio of 1:0.5:1. It is observed that the bulk density had shown an increasing trend with the increase in moisture content and the effect due to clearance on bulk density was negligible. Bulk density was slightly higher for the ratio 1:0.5:1 since there was 50 percent reduction in the volume of coir pith. This may be due to the lower density of the coir pith.

In the 1:1:1 ratio, porosity varied from 59.14 to 67.00 percent and 57.93 to 63.87 percent for the 1:0.5:1 ratio. It is clear that the porosity of grow bag mixtures decreased with the increase in moisture content. This is due to the increase in bulk density with moisture content. The ratio 1:1:1 had higher values of porosity for the respective moistures and clearances. It is due to the higher percentage of coir pith. Effect due to clearance on porosity was also negligible.

Fineness modulus varied from 4.89 to 6.18 at the ratio of 1:1:1and 5.11 to 6.42 at the ratio of 1:0.5:1. It increased with the increase in moisture content of mixture. More fine powder was obtained when the materials were dry. Effect due to clearance on fineness was negligible. Fineness modulus is slightly higher for the ratio 1:0.5:1. It is due to the presence of high proportion of cow dung particles with larger fineness modulus value.

Similarly, angle of repose varied between 43.24° and 57.00° at the ratio of 1:1:1 and 35.66° and 49.56° at the ratio of 1:0.5:1. It increased with the increase in moisture content. Effect due to clearance on angle of repose was insignificant. Angle of repose attained higher values for the ratio 1:0.5:1 since the mixture obtained was finer and angle of repose increases with the decrease in particle size of powder.

The value of pH varied between 6.7 and 6.9 at the ratio of 1:1:1 and 6.8 and 7 at the ratio of 1:1:1. It increased with the increase in moisture content of mixture. For a given ratio of mixture, at a particular moisture content, pH remained constant for all the clearances. Variation of clearances had no significance effect in pH values. The value of pH was found to be low at the ratio of 1:1:1. It is due to high volume of coir pith with acidic nature.

Electrical conductivity varied from 1.99 to 2.71 $dS.m^{-1}$ at the ratio of 1:1:1 and 2.08 to 2.68 $dS.m^{-1}$ at the ratio of 1:0.5:1. It increased with the increase in moisture content. It is presumed that the more the moisture content, the more the cations present in the solution of the media. The effect of change in clearances were not significant for the two different mixes on electrical conductivity.

At both the ratios, percentage deviation of bulk density from the reference values were found within the limit. A maximum percentage deviation of 4.17 percent was recorded at the ratio 1:1:1 while it was 3.06 percent for the ratio 1:0.5:1. Change in moisture or clearance or ratio have no influence in the deviation of uniformity. Bulk density measured from the bottom portion of the bag recorded maximum value whereas minimum value recorded at the top. The deviations were found to be minimum at the centre portion and marked a small increase toward both ends. It may be due to the fact that finer soil particles settled faster under gravity at bottom. At the same time the overall deviations were found to be minimum throughout the bag. Hence, it is concluded that the grow bag mixture is filled uniformly by using the newly developed machine.

The average weight of small bags were in the range of 1.82 to 2.34 kg at 1:1:1 ratio and 1.94 to 2.41 kg at 1:0.5:1 ratio. While, the average weights of medium grow bags varied between 3.93 and 4.45 kg and between 4.09 and 4.59 kg at 1:1:1 and 1:0.5:1 ratio respectively. The same trend was observed for large bags, i.e between 5.87 and 6.65 kg for 1:1:1 ratio of mix and between 6.01and 6.76 kg for 1:0.5:1 ratio. It is clear that the weight of three types of grow bag mixtures increased with the increase in moisture content of the materials. No noticeable effect was observed for the change in clearances. It was also found that the weights were slightly greater for the ratio 1:0.5:1 compared to 1:1:1 ratio. It was due to the fact that coir pith with lesser density is in higher proportion at 1:0.5:1 ratio.

In order to work continuously using the machine, it was found out that total time taken for taken for placing four empty bags and removal of the four filled bags was 40 s. Time of filling increased with the increase in moisture content of the materials for all types of bags. More time was recorded for the filling of mixture with proportion S: C: FYM as 1:0.5:1 irrespective of bag size. It may be due to the increased amount of dried cow dung, which was harder and larger in size. The time taken for pulverizing the dried cow dung is more compared to other raw materials. Time of filling the grow bags w.r.t the change in clearance was negligible.

Capacity of the machine varied between 211 and 259 $kg.h^{-1}$ for small bags, 300 and 355 $kg.h^{-1}$ for medium bags and 314 and 391 $kg.h^{-1}$ for large bags, at the ratio of 1:1:1. At 1:0.5:1 ratio, it varied between 201 and 247 $kg.h^{-1}$ for small bags, 289 and 345 $kg.h^{-1}$ for medium bags and 303 and 389 $kg.h^{-1}$ for large bags. Time consumption increased with the increase in moisture content. The effect due to clearance on capacity was negligible. While considering the two proportion of mix, capacity was found to be larger at the ratio 1: 1: 1 for all types of grow bags. It is due to less time of filling at the ratio 1:1:1. While considering the two proportion of mix, capacity was found to be larger at the ratio 1: 1: 1 for all types of grow bags. It is due to less time of filling at the ratio 1:1:1.

Capacity of the machine is also calculated based on the number of grow bags filled in one hour. More time of filling was recorded for large grow bags followed by medium and small bags. The number of bags filled in an hour varied in the range 91 to 131, 68 to 86 and 47 to 65 for small, medium and large grow bags respectively at the ratio of 1:1:1. Similarly it is observed that 85 to 120 small bags, 64 to 82 medium bags and 45 to 62 larger bags were filled at the ratio of 1:0.5:1. More number of small sized grow bags were filled in an hour compared to the other two bags. Number of bags filled decreased with the increase in moisture content of the materials irrespective of bag size. It is due to the increased time of filling. The effect due to clearance on number of bags filled was negligible. Number of bags filled was found to be larger at 1: 1: 1 ratio as less time was consumed for filling bags when compared with the other proportion. Proportion of cow dung was larger in 1:0.5:1 ratio and consumed more time for its pulverization.

Energy consumed varied between 0.048 and 0.081 kWh for four small sized grow bags, 0.087 and 0.117 kWh for medium sized grow bags and 0.124 and 0.180 kWh for large sized grow bags, at 1:1:1 ratio. For the ratio 1:0.5:1, it varied between 0.055 to 0.085 kWh, 0.092 to 0.127 kWh and 0.131 to 0.192 kWh for four small, medium and large sized grow bags respectively. It is concluded that the energy consumption increased as the moisture increased, for all the three types of bags selected. It was because more time and energy was required to pulverize materials of high moisture. As the quantity of mixture filled in the large bag is comparatively higher, more energy was consumed for its filling, followed by medium and small grow bags. The variation due to the clearance was observed minimum. More energy was consumed at 1:0.5:1 ratio as more time was consumed for the pulverization of dried cow dung.

Performance parameters were optimized with statistical analysis in SPSS software. The analysis included three replications at 5 percent level of significance. The mixture with ratio S: C: FYM as 1:1:1 at moisture levels of 10 and 15 percent were found to be significantly superior. Efficiency of 97.70 percent was obtained 15 percent moisture content and with less materials loss.

The properties of grow bag mixtures obtained were found to be on par with the recommended values of an ideal potting mixture. Thus, the evaluation proved the quality of grow bag mixtures for the production of plants. The performance evaluation of the machine was performed and the result was optimized using statistics. The machine worked fine for all clearance changes and there was no significant effect on the performance parameters. The ratio S: C: FYM as 1:1:1.with moisture content 15 percent proved to be superior for all clearances and bag sizes and forms the ideal working condition for the grow bag filling machine.

The cost of grow bag filling machine is Rs.49500. The hourly cost of operation for the machine is calculated as Rs.357.

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CHAPTER VI

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APPENDICES

APPENDIX I

Water holding capacity of grow bag mixtures

Sl. No:	Moisture content (%)	Clearance between blade and sieve (mm)	Water holding capacity (%)	
			S:C:FYM = 1:1:1	S:C:FYM = 1:0.5:1
1	10	15	162.01	121.89
		20	158.18	117.71
		25	159.52	123.21
2	15	15	163.16	117.08
		20	161.32	122.88
		25	165.02	120.59
3	20	15	166.19	123.71
		20	158.18	120.43
		25	159.74	124.22
4	25	15	160.64	118.34
		20	166.90	118.66
		25	159.07	119.62
5	30	15	157.73	117.08
		20	155.54	124.89
		25	161.32	120.43

APPENDIX II

Analysis of variance for variation of water holding capacity

(a) Analysis of variance for variation of water holding capacity at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	46.01	11.502	0.994	0.464^{NS}
Clearance	2	9.24	4.622	0.399	0.683^{NS}
Residuals	8	92.57	11.572		
Total	14	147.82			

(b) Analysis of variance for variation of water holding capacity at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	24.07	6.017	0.760	0.580^{NS}
Clearance	2	10.23	5.117	0.646	0.549^{NS}
Residuals	8	63.37	7.922		
Total	14	97.67			

(c) Analysis of variance for variation between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	12152	12152	1386	<2e-16**
Residuals	28	245	9		
Total	29	12397			

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX III

Bulk density of grow bag mixtures

Sl. No:	Moisture Content (%)	Clearance between blade and sieve (mm)	Bulk density ($g.cm^{-3}$)	
			S:C:FYM = 1:1:1	S:C:FYM = 1:0.5:1
1	10	15	0.470	0.552
		20	0.467	0.546
		25	0.462	0.542
2	15	15	0.493	0.561
		20	0.484	0.563
		25	0.487	0.559
3	20	15	0.528	0.583
		20	0.525	0.582
		25	0.519	0.586
4	25	15	0.548	0.609
		20	0.553	0.614
		25	0.559	0.608
5	30	15	0.571	0.626
		20	0.572	0.627
		25	0.569	0.631

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APPENDIX IV

Analysis of variance for variation of bulk density of mixtures

(a) Analysis of variance for variation of bulk density at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.02279	0.00570	281.61	23e-08 **
Clearance	2	0.00002	0.00001	0.498	0.626^{NS}
Residuals	8	0.00016	0.00002		
Total	14	0.02297			

(b) Analysis of variance for variation of bulk density at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.013601	3.4e-03	277.948	1.3e-08 **
Clearance	2	0.000004	2.0e-06	0.169	0.847^{NS}
Residuals	8	0.000098	1.2e-05		
Total	14	0.013703			

(c) Analysis of variance for variation of bulk density between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.03214	0.03214	24.54	3.15e-05**
Residuals	28	0.03668	0.00131		
Total	29	0.06882			

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX V

Porosity of grow bag mixtures

Sl. No:	Moisture Content (%)	Clearance between blade and sieve (mm)	Porosity (%)	
			S:C:FYM = 1:1:1	S:C:FYM = 1:0.5:1
1	10	15	66.43	63.20
		20	66.64	63.60
		25	67.00	63.87
2	15	15	64.79	62.60
		20	65.43	62.47
		25	65.21	62.73
3	20	15	62.29	61.13
		20	62.50	61.20
		25	62.93	60.93
4	25	15	60.86	59.40
		20	60.50	59.07
		25	60.07	59.47
5	30	15	59.21	58.27
		20	59.14	58.20
		25	59.36	57.93

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APPENDIX VI

Analysis of variance for variation of porosity of porosity

(a) Analysis of variance for variation of porosity at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	116.30	29.075	280.844	1.24e-08 **
Clearance	2	0.10	0.050	0.485	0.633^{NS}
Residuals	8	0.83	0.104		
Total	14	117.23			

(b) Analysis of variance for variation of porosity at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	60.44	15.111	275.724	1.34e-08 **
Clearance	2	0.02	0.009	0.161	0.854^{NS}
Residuals	8	0.44	0.055		
Total	14	60.90			

(c) Analysis of variance for variation of porosity between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	26.68	26.677	4.193	0.0401*
Residuals	28	178.13	6.362		
Total	29	204.81			

*Significant at 5% level **Significant at 1% level NS: Non-significant

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APPENDIX VII

Fineness modulus of grow bag mixtures

Sl. No	Moisture content (%)	Clearance between blade and sieve (mm)	Fineness modulus	
			S:C:FYM = 1:1:1	S:C:FYM = 1:0.5:1
1	10	15	4.93	5.11
		20	4.89	5.21
		25	4.95	5.17
2	15	15	5.28	5.41
		20	5.24	5.45
		25	5.31	5.51
3	20	15	5.57	5.76
		20	5.54	5.79
		25	5.58	5.87
4	25	15	5.73	6.12
		20	5.84	6.05
		25	5.78	5.94
5	30	15	6.18	6.35
		20	6.10	6.42
		25	6.04	6.31

APPENDIX VIII

Analysis of variance for variation of fineness modulus of mixtures

(a) Analysis of variance for variation of fineness modulus at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	2.4902	0.6225	243.180	2.2e-08 **
Clearance	2	0.0007	0.0003	0.128	0.882^{NS}
Residuals	8	0.0205	0.0026		
Total	14	2.5114			

(b) Analysis of variance for variation of fineness modulus at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	2.6590	0.6650	146.902	1.61e-07 **
Clearance	2	0.0003	0.0015	0.337	0.723^{NS}
Residuals	8	0.0362	0.0045		
Total	14	2.6955			

(c) Analysis of variance for variation of fineness modulus between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.411	0.4107	2.207	0.0149*
Residuals	28	5.210	0.1861		
Total	29	5.621			

*Significant at 5% level **Significant at 1% level NS: Non-significant

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APPENDIX IX

Angle of repose of grow bag mixtures

Sl. No	Moisture content (%)	Clearance between blade and sieve (mm)	Angle of repose, (degree)	
			S:C:FYM = 1:1:1	S:C:FYM = 1:0.5:1
1	10	15	45.86	37.68
		20	43.24	35.66
		25	44.03	36.80
2	15	15	48.32	39.81
		20	46.66	40.49
		25	47.68	41.07
3	20	15	50.35	43.30
		20	49.74	43.14
		25	48.04	42.88
4	25	15	52.37	47.59
		20	52.94	46.92
		25	51.73	47.23
5	30	15	57.00	46.53
		20	53.94	48.93
		25	55.44	49.56

APPENDIX X

Analysis of variance for variation of angle of repose of mixtures

(a) Analysis of variance for variation of angle of repose at ratio 1:1:1

Source of variation	**DF**	**SS**	**MS**	**F - value**	**Significance level**
Moisture content	4	277.21	69.30	74.663	2.27e-06 **
Clearance	2	0.85	0.42	0.457	0.649^{NS}
Residuals	8	7.43	0.93		
Total	14	285.49			

(b) Analysis of variance for variation of angle of repose at ratio 1:0.5:1

Source of variation	**DF**	**SS**	**MS**	**F - value**	**Significance level**
Moisture content	4	219.47	54.87	68.521	3.16e-06 **
Clearance	2	6.89	3.44	4.302	0.054^{NS}
Residuals	8	6.41	0.80		
Total	14	222.77			

(c) Analysis of variance for variation of angle of repose between two ratios

Source of variation	**DF**	**SS**	**MS**	**F - value**	**Significance level**
Ratio	1	331.7	331.7	17.92	2.24e-04**
Residuals	28	518.3	18.5		
Total	29	850			

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XI

pH of grow bag mixtures

Sl. No:	Moisture content (%)	Clearance between sieve and the blade (mm)	pH	
			S:C:FYM = 1:1:1	S:C:FYM = 1:1:1
1	10	15	6.70	6.80
		20	6.70	6.80
		25	6.70	6.80
2	15	15	6.76	6.86
		20	6.76	6.86
		25	6.76	6.86
3	20	15	6.80	6.90
		20	6.80	6.90
		25	6.80	6.90
4	25	15	6.86	6.93
		20	6.86	6.93
		25	6.86	6.93
5	30	15	6.90	7.00
		20	6.90	7.00
		25	6.90	7.00

APPENDIX XII

Analysis of variance for variation of pH of mixtures

(a) Analysis of variance for variation of pH at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.075	0.018	7.3e+28	<2e-16 **
Clearance	2	0.000	0.00	1.024e+00	0.402^{NS}
Residuals	8	0.000	0.00		
Total	14	0.075			

(b) Analysis of variance for variation of pH at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.067	0.016	2.384e+28	<2e-16 **
Clearance	2	0.000	0.00	1.022e+00	0.402^{NS}
Residuals	8	0.000	0.00		
Total	14	0.067			

(c) Analysis of variance for variation of pH between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.066	0.066	12.99	0.0012**
Residuals	28	0.142	0.005		
Total	29	0.208			

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XIII

Electrical conductivity of mixtures

Sl. No:	Moisture content (%)	Clearance between blade and sieve (mm)	Electrical Conductivity ($dS.m^{-1}$)	
			S:C:FYM = 1:1:1	S:C:FYM = 1:0.5:1
1	10	15	2.01	2.13
		20	1.99	2.08
		25	2.03	2.10
2	15	15	2.14	2.26
		20	2.19	2.27
		25	2.07	2.19
3	20	15	2.43	2.33
		20	2.47	2.31
		25	2.46	2.39
4	25	15	2.49	2.42
		20	2.56	2.45
		25	2.53	2.52
5	30	15	2.68	2.68
		20	2.71	2.58
		25	2.70	2.66

APPENDIX IV

Analysis of variance for variation of electrical conductivity of mixtures

(a) Analysis of variance for variation of electrical conductivity at ratio 1:1:1

Source of variation	**DF**	**SS**	**MS**	**F - value**	**Significance level**
Moisture content	4	0.971	0.242	223.02	3.1e-08 **
Clearance	2	0.003	0.001	1.452	0.29^{NS}
Residuals	8	0.008	0.001		
Total	14	0.982			

(b) Analysis of variance for variation of electrical conductivity at ratio 1:0.5:1

Source of variation	**DF**	**SS**	**MS**	**F - value**	**Significance level**
Moisture content	4	0.508	0.1272	62.665	4.46e-06 **
Clearance	2	0.003	0.0015	0.778	0.491^{NS}
Residuals	8	0.016	0.002		
Total	14	0.527			

(c) Analysis of variance for variation of electrical conductivity between two ratios

Source of variation	**DF**	**SS**	**MS**	**F - value**	**Significance level**
Ratio	1	0.0003	0.0002	0.005	0.944
Residuals	28	1.5110	0.0539		
Total	29	0.208			

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XV

(a) Uniformity of mixtures

Ratios	Bag type	Uniformity of mixture (Deviations from reference bulk density, %)														
		Moisture content 10%			Moisture content 15%			Moisture content 20%			Moisture content 25%			Moisture content 30%		
		Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve		
		15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)
1:1:1	Top	-1.90	-2.16	-3.92	-1.83	-2.05	-2.69	-1.33	-1.89	-1.53	-1.27	-0.36	-2.71	-1.41	0.17	-0.87
	Middle	0.63	0.65	-0.65	0.41	-1.23	-0.83	-0.38	0.19	-0.19	0.54	0.73	-0.72	2.65	1.38	0.52
	Bottom	1.90	2.38	0.87	1.22	2.05	0.62	2.47	0.76	1.15	4.17	2.55	1.81	3.53	3.11	3.13
1:0.5:1	Top	-2.87	-2.01	-1.86	-1.79	-2.14	-3.06	-3.45	-1.88	-2.07	-2.99	-2.79	-2.48	-1.59	-3.05	-3.34
	Middle	-0.36	0.18	-0.56	-0.18	-0.71	-0.72	-0.86	0.68	-1.03	-1.00	-1.48	-1.32	-0.64	-2.09	-1.43
	Bottom	1.08	2.19	1.86	1.43	1.25	0.54	0.86	1.37	0.34	0.83	1.15	2.15	1.43	0.96	1.43

(b) Reference bulk density calculated for uniformity evaluation

Reference bulk density ($g.cm^{-3}$)				
Sl. No:	Moisture content (%)	Clearance between blade and sieve (mm)	Uniformity (%)	
			S:C:FYM = 1:1:1	S:C:FYM = 1:0.5:1
1	10	15	0.473	0.558
		20	0.462	0.548
		25	0.459	0.539
2	15	15	0.493	0.559
		20	0.488	0.561
		25	0.484	0.556
3	20	15	0.526	0.58
		20	0.528	0.585
		25	0.522	0.581
4	25	15	0.551	0.602
		20	0.55	0.61
		25	0.554	0.605
5	30	15	0.567	0.629
		20	0.578	0.622
		25	0.576	0.628

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(c) Bulk density from different portions of bag

Bulk density values calculated from different portions of bags for uniformity measurement																
		Moisture content 10%			Moisture content 15%			Moisture content 20%			Moisture content 25%			Moisture content 30%		
		Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve		
Ratios	Portion	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)
1:1:1	Top	0.464	0.452	0.441	0.484	0.478	0.471	0.519	0.518	0.514	0.544	0.548	0.539	0.559	0.579	0.571
	Middle	0.476	0.465	0.456	0.495	0.482	0.48	0.524	0.529	0.521	0.554	0.554	0.550	0.582	0.586	0.579
	Bottom	0.482	0.473	0.463	0.499	0.498	0.487	0.539	0.532	0.528	0.574	0.564	0.564	0.584	0.596	0.594
1:0.5:1	Top	0.542	0.537	0.529	0.549	0.549	0.539	0.56	0.574	0.569	0.584	0.593	0.59	0.619	0.603	0.607
	Middle	0.556	0.549	0.536	0.558	0.557	0.552	0.575	0.589	0.575	0.596	0.601	0.597	0.625	0.609	0.619
	Bottom	0.564	0.560	0.549	0.567	0.568	0.559	0.585	0.593	0.583	0.607	0.617	0.618	0.638	0.628	0.637

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APPENDIX XVI

Analysis of variance for variation of percentage deviation of uniformity

(a) Analysis of variance for variation of percentage deviation of uniformity at three different portions of a filled bag at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Portions of bag	2	110.12	55.06	53.34	2.96e-12 **
Residuals	42	43.35	1.03		
Total	44	153.47			

(b) Analysis of variance for variation of percentage deviation of uniformity at three different portions of a filled bag at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Portions of bags	2	105.66	52.83	138.4	<2e-16
Residuals	42	16.03	0.38		
Total	44	121.69			

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XVII

Average weight of filled grow bags

Ratios	Bag type	Average weight of filled grow bags (Kg)														
		Moisture content 10%			Moisture content 15%			Moisture content 20%			Moisture content 25%			Moisture content 30%		
		Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve		
		15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)
1:1:1	Small	1.87^a	1.85^a	1.82^a	1.92^a	1.93^a	1.95^b	2.16^c	2.11^c	2.10^c	2.25^d	2.19^d	2.24^d	2.32^d	2.28^d	2.34^d
	Medium	4.00^a	3.96^a	3.93^a	4.18^b	4.12^a	4.14^b	4.22^b	4.19^b	4.16^b	4.30^c	4.24^c	4.26^c	4.45^d	4.38^d	4.41^d
	Large	5.87^a	5.88^a	5.91^a	6.15^a	6.17^a	6.18^a	6.23^b	6.27^c	6.26^c	6.43^d	6.46^d	6.40^d	6.61^d	6.57^d	6.65^d
1:0.5:1	Small	1.95^b	1.97^b	1.94^b	2.15^c	2.11^c	2.15^c	2.21^d	2.23^d	2.19^d	2.29^d	2.28^d	2.31^d	2.38^d	2.41^d	2.37^d
	Medium	4.11^a	4.09^a	4.12^a	4.26^c	4.27^c	4.24^b	4.38^d	4.31^d	4.35^d	4.46^d	4.42^d	4.48^d	4.57^d	4.54^d	4.59^d
	Large	6.04^a	6.02^a	6.01^a	6.28^c	6.21^b	6.24^b	6.36^c	6.42^d	6.35^c	6.53^a	6.55^d	6.58^d	6.69^d	6.76^d	6.74^d

APPENDIX XVIII

Analysis of variance for variation of weights of bags filled

(a) Analysis of variance for variation of weights of small bags filled at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.4602	0.11506	178.388	7.49e-08 **
Clearance	2	0.0026	0.00129	1.995	0.198^{NS}
Residuals	8	0.0052	0.00064		
Total	14	0.4670	0.11699		

(b) Analysis of variance for variation of weights of small bags filled at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.3253	0.08132	185.529	6.41e-08 **
Clearance	2	0.0002	0.00008	0.183	0.837^{NS}
Residuals	8	0.0035	0.00044		
Total	14	0.3280	0.08174		

(c) Analysis of variance for variation of weights of small bags between at two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.0864	0.08640	3.036	0.0424*
Residuals	28	0.7969	0.02846		
Total	29	0.8833	0.11486		

*Significant at 5% level **Significant at 1% level NS: Non-significant

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(d) Analysis of variance for variation of weights of medium bags filled at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.3265	0.08162	365.48	4.37e-09 **
Clearance	2	0.0087	0.00434	19.43	0.0849 NS
Residuals	8	0.0018	0.00022		
Total	14	0.3370	0.08618		

(e) Analysis of variance for variation of weights of medium bags filled at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.3764	0.09411	213.072	3.71e-08 **
Clearance	2	0.0030	0.00150	3.396	0.0855 NS
Residuals	8	0.0035	0.00044		
Total	14	0.3829	0.09605		

(f) Analysis of variance for variation of weights of medium bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.1688	0.16875	6.563	0.0161 *
Residuals	28	0.7199	0.02571		
Total	29	0.8887	0.19146		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(g) Analysis of variance for variation of weights of large bags filled at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.8973	0.22432	299.764	9.6e-09 **
Clearance	2	0.0012	0.00061	0.811	0.478^{NS}
Residuals	8	0.0060	0.00075		
Total	14	0.9045	0.22548		

(h) Analysis of variance for variation of weights of large bags filled at ratio1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.8949	0.22373	192.591	5.53e-08 **
Clearance	2	0.0004	0.00019	0.161	0.854^{NS}
Residuals	8	0.0093	0.00116		
Total	14	0.9046	0.22508		

(i) Analysis of variance for variation of weights of large bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.1009	0.10092	1.562	0.0222*
Residuals	28	1.8091	0.06461		
Total	29	1.9100	0.16553		

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XIX

Time taken for filling different sizes of grow bags

Ratios	Bag type	Time taken for filling grow bags (s)														
		Moisture content 10%			Moisture content 15%			Moisture content 20%			Moisture content 25%			Moisture content 30%		
		Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve		
		15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)
1:1:1	Small	114^{a}	110^{a}	111^{a}	118^{b}	114^{a}	116^{a}	135^{c}	131^{c}	133^{c}	141^{d}	139^{d}	137^{c}	158^{d}	154^{d}	149^{d}
	Medium	167^{a}	168^{a}	167^{a}	173^{a}	170^{a}	172^{a}	183^{c}	181^{c}	179^{d}	193^{d}	194^{d}	190^{d}	211^{c}	210^{d}	209^{d}
	Large	222^{a}	225^{a}	224^{a}	230^{a}	231^{a}	232^{b}	245^{c}	247^{c}	249^{c}	258^{d}	264^{d}	263^{d}	297^{d}	301^{d}	304^{d}
1:0.5:1	Small	120^{b}	121^{b}	120^{b}	133^{c}	128^{c}	131^{c}	139^{d}	141^{d}	143^{d}	151^{d}	153^{d}	154^{d}	166^{d}	163^{d}	170^{d}
	Medium	176^{d}	175^{d}	177^{b}	180^{a}	181^{c}	180^{b}	195^{d}	191^{b}	194^{d}	204^{d}	208^{d}	206^{d}	223^{d}	226^{d}	223^{d}
	Large	233^{b}	234^{b}	231^{b}	237^{b}	234^{b}	236^{b}	258^{d}	261^{d}	255^{d}	280^{d}	276^{d}	274^{d}	311^{d}	321^{d}	315^{d}

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APPENDIX XX

. **Analysis of variance for variation of time for filling bags**

(a) Analysis of variance for variation of time for filling small bags at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	3540	885	285.484	1.16e-08 **
Clearance	2	49	24.3	7.25	0.131^{NS}
Residuals	8	25	3.1		
Total	14	3614	912.4		

(b) Analysis of variance for variation of time for filling small bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	3914	978.4	223.217	3.09e-08 **
Clearance	2	16	7.8	1.779	0.229^{NS}
Residuals	8	35	4.4		
Total	14	3965	990.6		

(c) Analysis of variance for variation of time for filling small bags between at two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	998	997.6	3.686	0.0451*
Residuals	28	7578	270.6		
Total	29	8576	1268.2		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(d) Analysis of variance for variation of time for filling medium bags at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	3550	887.4	511.981	1.14e-09 **
Clearance	2	10	5.1	2.923	0.111 NS
Residuals	8	14	1.7		
Total	14	3574	894.2		

(e) Analysis of variance for variation of time for filling medium bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	4610	1152.4	337.386	3.83e-09 **
Clearance	2	1	0.5	0.153	0.861 NS
Residuals	8	24	3.1		
Total	14	4635	1156		

(f) Analysis of variance for variation of time for filling medium bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	986	986.1	3.364	0.0161 *
Residuals	28	8209	293.2		
Total	29	9195	1279.3		

*Significant at 5% level   **Significant at 1% level   NS: Non-significant

(g) Analysis of variance for variation of time for filling large bags at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	11182	2795.6	1471.37	1.7e-11 **
Clearance	2	45	22.4	11.79	0.0512^NS
Residuals	8	15	1.9		
Total	14	11242	2819.9		

(h) Analysis of variance for variation of time for filling large bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	13950	3488	376.356	3.89e-09 **
Clearance	2	23	11	1.216	0.346^NS
Residuals	8	74	9		
Total	14	14047	3508		

(i) Analysis of variance for variation of time for filling large bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	897	896.5	0.993	3.74e-06*
Residuals	28	25289	903.2		
Total	29	26186	1799.7		

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XXI

Capacity of the machine calculated for different grow bag sizes

		Capacity of the machine ((Kg.hr^{-1})														
		Moisture content 10%			Moisture content 15%			Moisture content 20%			Moisture content 25%			Moisture content 30%		
Ratios	Bag type	Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve		
		15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)
1:1:1	Small	252^{a}	248^{a}	251^{a}	234^{b}	244^{a}	242^{a}	230^{b}	232^{b}	227^{c}	230^{b}	227^{c}	235^{b}	211^{d}	213^{d}	226^{c}
	Medium	354^{a}	352^{a}	355^{a}	348^{a}	349^{a}	347^{a}	332^{b}	333^{b}	335^{b}	321^{c}	315^{c}	323^{c}	304^{d}	300^{d}	304^{d}
	Large	390^{a}	391^{a}	390^{a}	385^{a}	385^{a}	384^{a}	366^{b}	366^{b}	362^{b}	359^{b}	352^{c}	350^{c}	320^{d}	314^{d}	315^{d}
1:0.5:1	Small	243^{b}	247^{b}	245^{b}	233^{d}	237^{a}	236^{a}	229^{b}	228^{c}	221^{c}	218^{c}	215^{d}	216^{d}	206^{d}	213^{d}	201^{d}
	Medium	344^{a}	346^{a}	345^{b}	341^{a}	340^{a}	339^{a}	323^{c}	325^{b}	323^{c}	315^{c}	306^{d}	313^{c}	295^{d}	289^{d}	296^{d}
	Large	387^{a}	387^{a}	389^{a}	382^{a}	382^{a}	381^{a}	355^{c}	354^{c}	359^{c}	336^{d}	342^{c}	346^{d}	310^{d}	303^{d}	308^{d}

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APPENDIX XXII

Analysis of variance for variation of capacity for filling bags

(a) Analysis of variance for variation of capacity for filling small bags at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	1895.1	473.8	20.855	3.39e-09 **
Clearance	2	60.9	30.5	1.341	0.0572NS
Residuals	8	181.7	22.7		
Total	14	2137.7	527		

(b) Analysis of variance for variation of capacity for filling small bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	2745.7	686.4	62.498	4.51e-06 **
Clearance	2	44.1	22.1	2.009	0.196^{NS}
Residuals	8	87.9	11.0		
Total	14	2877.7	719.5		

(c) Analysis of variance for variation of capacity for filling small bags between at two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	433	433.2	2.418	0.0431*
Residuals	28	5015	179.1		
Total	29	5448	612.3		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(d) Analysis of variance for variation of capacity for filling medium bags at ratio1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	5215	1303.8	312.9	8.09e-09 **
Clearance	2	23	11.7	2.8	0.12^{NS}
Residuals	8	33	4.2		
Total	14	5271	1319.7		

(e) Analysis of variance for variation of capacity for filling medium bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	5367	1341.8	169.139	9.4e-08 **
Clearance	2	17	8.3	1.042	0.396^{NS}
Residuals	8	63	7.9		
Total	14	5447	1358		

(f) Analysis of variance for variation of capacity for filling medium bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	581	580.8	1.517	0.0428 *
Residuals	28	10719	382.8		
Total	29	11300	963.6		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(g) Analysis of variance for variation of capacity for filling large bags at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	10436	2608.9	516.614	1.1e-09**
Clearance	2	37	18.5	3.657	0.0745 NS
Residuals	8	40	5.1		
Total	14	10513	2632.5		

(h) Analysis of variance for variation of capacity for filling large bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	12809	3202	379.11	3.75e-09 **
Clearance	2	27	13	1.573	0.265 NS
Residuals	8	67	8		
Total	14	12903	3223		

(i) Analysis of variance for variation of capacity for filling large bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	389	388.8	0.465	0.0401*
Residuals	28	23416	836.3		
Total	29	23805	12251		

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XXIII

Number of grow bags filled in one hour different grow bags

Ratios	Bag type	Number of grow bags filled in one hour														
		Moisture content 10%			Moisture content 15%			Moisture content 20%			Moisture content 25%			Moisture content 30%		
		Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve		
		15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)
1:1:1	Small	126^{a}	131^{a}	130^{a}	122^{a}	126^{a}	124^{a}	107^{d}	110^{c}	108^{c}	102^{d}	104^{d}	105^{d}	91^{d}	94^{d}	97^{d}
	Medium	86^{a}	86^{a}	86^{a}	83^{a}	85^{a}	84^{a}	79^{c}	80^{c}	80^{b}	75^{d}	74^{d}	76^{d}	68^{d}	69^{d}	69^{d}
	Large	65^{a}	64^{a}	64^{a}	63^{a}	62^{a}	62^{b}	59^{c}	58^{c}	58^{c}	56^{d}	55^{d}	55^{d}	48^{d}	48^{d}	47^{d}
1:0.5:1	Small	120^{b}	119^{b}	120^{b}	108^{c}	113^{c}	110^{c}	104^{d}	102^{d}	101^{d}	95^{d}	94^{d}	94^{d}	87^{d}	88^{d}	85^{d}
	Medium	82^{b}	82^{b}	81^{b}	80^{c}	80^{c}	80^{c}	74^{d}	75^{d}	74^{d}	71^{d}	69^{d}	70^{d}	65^{d}	64^{d}	65^{d}
	Large	62^{b}	62^{b}	62^{a}	61^{c}	62^{b}	61^{b}	56^{d}	55^{d}	56^{d}	51^{d}	52^{d}	53^{d}	46^{d}	45^{d}	46^{d}

APPENDIX XXIV

Analysis of variance for variation of number of bags filled

(a) Analysis of variance for variation of number of small bags filled at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	2519.1	629.8	389.55	3.39e-09 **
Clearance	2	36.4	18.2	11.26	0.0572NS
Residuals	8	12.9	1.6		
Total	14	2568.4	649.6		

(b) Analysis of variance for variation of number of small bags filled at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	2020	505	206.122	4.23e-08 **
Clearance	2	3.7	1.9	0.762	0.498^{NS}
Residuals	8	19.6	2.4		
Total	14	2043.3	509.3		

(c) Analysis of variance for variation of number of small bags filled between at two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	626	625.6	3.799	0.0414*
Residuals	28	4612	164.7		
Total	29	5238	790.3		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(d) Analysis of variance for variation of number of medium bags filled at ratio1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	590.0	147.50	327.778	6.73e-09 **
Clearance	2	1.7	0.87	1.926	0.208^{NS}
Residuals	8	3.6	0.45		
Total	14	595.3	148.82		

(e) Analysis of variance for variation of number of medium bags filled at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	593.7	148.43	342.538	5.65e-09 **
Clearance	2	0.5	0.27	0.615	0.564^{NS}
Residuals	8	3.5	0.43		
Total	14	597.7	149.13		

(f) Analysis of variance for variation of number of medium bags filled between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	154.1	154.13	3.617	0.0473 *
Residuals	28	1193.1	42.61		
Total	29	1347.2	196.74		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(g) Analysis of variance for variation of number of large bags filled at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	516.3	129.07	1936	5.67e-12**
Clearance	2	4.8	3.40	21	0.0655^{NS}
Residuals	8	0.5	0.07		
Total	14	521.6	132.54		

(h) Analysis of variance for variation of number of large bags filled at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	555.3	138.83	320.385	7.373e-09 **
Clearance	2	0.5	0.27	0.615	0.564^{NS}
Residuals	8	3.5	0.43		
Total	14	559.3			

(i) Analysis of variance for variation of number of large bags filled between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	38.5	38.53	1	0.0326*
Residuals	28	1078.9	38.53		
Total	29	1117.4	77.06		

*Significant at 5% level **Significant at 1% level NS: Non-significant

APPENDIX XXV

Energy consumption of machine for filling different size grow bags

Ratios	Bag type	Energy consumption of machine (KWh)														
		Moisture content 10%			Moisture content 15%			Moisture content 20%			Moisture content 25%			Moisture content 30%		
		Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve			Clearance between blade and sieve		
		15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)	15 (mm)	20 (mm)	25 (mm)
1:1:1	Small	0.051^{a}	0.048^{a}	0.049^{a}	0.053^{a}	0.051^{a}	0.052^{a}	0.065^{a}	0.062^{a}	0.064^{a}	0.069^{a}	0.068^{a}	0.066^{a}	0.081^{a}	0.078^{a}	0.074^{a}
	Medium	0.087^{a}	0.087^{a}	0.087^{a}	0.091^{a}	0.089^{a}	0.090^{a}	0.098^{b}	0.096^{b}	0.095^{b}	0.105^{d}	0.105^{d}	0.103^{d}	0.117^{d}	0.116^{d}	0.115^{d}
	Large	0.124^{a}	0.126^{a}	0.126^{a}	0.130^{a}	0.131^{a}	0.131^{b}	0.140^{c}	0.141^{c}	0.143^{c}	0.149^{d}	0.153^{d}	0.152^{d}	0.176^{d}	0.178^{d}	0.180^{d}
1:0.5:1	Small	0.055^{a}	0.055^{a}	0.055^{a}	0.064^{a}	0.060^{a}	0.062^{b}	0.068^{a}	0.069^{a}	0.070^{a}	0.076^{a}	0.077^{a}	0.078^{a}	0.086^{a}	0.084^{a}	0.089^{a}
	Medium	0.093^{b}	0.092^{a}	0.094^{b}	0.096^{b}	0.096^{c}	0.096^{c}	0.106^{d}	0.103^{d}	0.105^{d}	0.112^{d}	0.115^{d}	0.113^{d}	0.125^{d}	0.127^{d}	0.125^{d}
	Large	0.132^{b}	0.133^{b}	0.131^{b}	0.135^{b}	0.133^{b}	0.134^{b}	0.149^{d}	0.151^{d}	0.147^{d}	0.164^{d}	0.161^{d}	0.160^{d}	0.185^{d}	0.192^{d}	0.188^{d}

APPENDIX XXVI

Analysis of variance for variation of energy consumption for filling bags

(a) Analysis of variance for variation of energy consumption for filling small bags at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.0016223	0.0004056	182.962	6.78e-08 **
Clearance	2	0.0000229	0.0000115	5.173	0.0562 NS
Residuals	8	0.0000177	0.0000022		
Total	14	0.0016629	0.0004193		

(b) Analysis of variance for variation of energy consumption for filling small bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.0018171	0.0004543	219.806	3.28e-08 ***
Clearance	2	0.0000081	0.0000041	1.968	0.202 NS
Residuals	8	0.0000165	0.0000021		
Total	14	0.0018417	0.0004605		

(c) Analysis of variance for variation of energy consumption for filling small bags between at two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.000456	0.0004563	3.646	0.0465*
Residuals	28	0.003505	0.0001252		
Total	29	0.003961	0.0005815		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(d) Analysis of variance for variation of energy consumption for filling medium bag at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	1.6e-04	4.1e-04	686.5	3.5e-19 **
Clearance	2	6.5e-06	3.3e-06	5.4	0.0522^{NS}
Residuals	8	4.8e-06			
Total	14	1.6e-03	4.1e-04		

(e) Analysis of variance for variation energy consumption for filling medium bags ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	2.13e-03	5.3e-05	307.173	8.71e-09 **
Clearance	2	1.00e-07	1.0e-07	0.038	0.962^{NS}
Residuals	8	8.139e-05	1.7e-06		
Total	14	2.211e-03	5.48e-05		

(f) Analysis of variance for variation of energy consumption for filling medium bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	0.000456	0.0004563	3.36	0.0475 *
Residuals	28	0.003803	0.0001358		
Total	29	0.004259	0.0005921		

*Significant at 5% level **Significant at 1% level NS: Non-significant

(g) Analysis of variance for variation of energy consumption for filling large bags at ratio 1:1:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.0016223	0.0004056	182.96	6.78e-08 **
Clearance	2	0.0000229	0.0000115	5.17	0.0562^{NS}
Residuals	8	0.0000177	0.0000022		
Total	14	0.0016629	0.0004193	188.13	

(h) Analysis of variance for variation of energy consumption for filling large bags at ratio 1:0.5:1

Source of variation	DF	SS	MS	F - value	Significance level
Moisture content	4	0.0018171	0.0004543	219.806	3.28e-08 **
Clearance	2	0.0000081	0.0000041	1.968	0.202^{NS}
Residuals	8	0.0000165	0.0000021		
Total	14	0.0018417	0.0004605		

(i) Analysis of variance for variation of energy consumption for filling large bags between two ratios

Source of variation	DF	SS	MS	F - value	Significance level
Ratio	1	4.5e-04	4.5e-04	3.646	0.0465**
Residuals	28	3.5e-03	1.2e-04		
Total	29	3.9e-03	5.1e-04		

*Significant at 5% level **Significant at 1% level NS: Non-significant

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APPENDIX XXVII

Cost of KAU Manure Pulverizer (Rs) = 38,500 (including GST) as on date

Material cost (Rs) for grow bag filling unit = 6,500

Labour cost = 4,500

Total cost of grow bag filling machine (Rs) = 38,500+6,500+4,500

= 49,500

14.1 Cost economics of the grow bag filling machine

A) Basic information

i) Cost of the unit (Rs) : 49,500

ii) Useful life in years : 10

iii) Rate of interest (%) : 10

iv) Hours of use per year : 100

v) Salvage value (10% of investment cost) : 4950

vi) Capacity of machine (kg h^{-1}) : 500

vii) Electricity required (kW h^{-1}) : 8.2

B) Cost of economics of the machine

I. Fixed cost

i) Depreciation cost per year (Rs) $= \frac{\text{Initial cost} - \text{Salvage value}}{\text{Useful life}}$

$= \frac{49,500 - 4,950}{10}$

= 4,455

ii) Interest on investment per year (Rs) = ½ (Cost of unit +salvage value) x (interest rate)

$= \left(\frac{49500+4950}{2}\right) \times 0.10$

= 2,723

iii) Taxes, insurance and shelter per year (Rs) = cost of unit × 0.02

$= 49,500 \times 0.02$

$= 990$

iv) Total fixed cost per year (Rs) $= 4,455 + 2,723 + 990$

$= 8168$

v) Total fixed cost per hr (Rs) $= \frac{\text{Total fixed cost per year}}{\text{Hours of use per year}}$

$= \frac{8168}{100}$

$= 81.68$

II .Variable cost

i) Repair and maintenance per hour (Rs) $= \frac{\text{Cost of unit} \times 0.5}{1000}$

$= \frac{49,500 \times 0.5}{1000}$

$= 24.75$

ii) Cost of unit electricity = 6.10 R.S. per kW h

Power consumption of the machine = 8.2 kW h

Total cost of electricity (Rs) $= 6.10 \times 8.2 = 50$

Labour cost per hour, Rs = 100

No. of labours = 2

Total labour cost = 200

iii) Total variable cost (Rs) $= 25 + 50 + 200$

$= 275$

Total cost per hour (Rs.) = fixed cost + variable cost

$= 82 + 275$

$= 357$

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DEVELOPMENT AND TESTING OF POTTING MIXTURE FILLING MACHINE FOR FILLING GROW BAGS

by

AMAL DEV J

(2017-18-007)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Technology

In

Agricultural Engineering

(Farm Machinery and Power Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Farm Machinery and Power Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR-679573, MALAPPURAM

KERALA, INDIA

2019

ABSTRACT

Grow bag cultivation is getting popular in our state due to urbanisation. It necessitated easy method of filling grow bags as per the favourable agronomic conditions for crop growth. A grow bag filling machine was hence developed and tested for filling grow bags of different size. The machine was developed by modifying the KAU manure pulverizer by suitably fixing a collecting hopper beneath the sieve, grow bag holders attached to one leg of the stand for holding different bags and pedal for controlling the filling. The machine consists of an electric motor, a feeding chute, pulverizing drum, transmission unit, rotating blades, sieve and a supporting stand. Materials were pulverized and mixed due to rotations of the blade which caused the cutting and shearing actions and got pulverized in the clearance between the blade and the sieve. The grow bag mixture was discharged through the sieve and got collected in the bottom hopper. A pedal operated valve was inserted into the small hopper to facilitate metered discharge of the potting media. As and when it is allowed to open a metered quantity of the mixture was discharged into the grow bags placed below it.

The machine was tested to determine its performance and to optimize the machine parameters and material parameters at different moisture contents of 10,15,20,25 and 30 percent, clearances of 15, 20 and 25 mm, two ratios of soil: coir pith: FYM as 1:1:1 and 1:0.5:1 mixture and for three bag sizes of small medium and large. Dried soil, coir pith and FYM get pulverized, mixed and filled in the grow bags. The properties of grow bag mixtures obtained were found out and were on par with the ideal recommendations. The properties such as water holding capacity (165.02 percent), bulk density (0.493 g.cm$^{-3)}$, porosity (65.43 percent), fineness modulus (5.31), angle of repose (46.66°), pH (6.76), electrical conductivity (2.19 dS.m$^{-1)}$ and uniformity of mixture were observed at the ratio 1:1:1 (S:C:FYM) at the moisture content of 15 percent. Performance parameters such as weight of bags filled (6.18 kg) time of operation (230 s), capacity of the machine (385 kg.h^{-1}), number of bags filled (63) and energy consumption (0.31 kWh for four bags) were obtained with an overall efficiency of 97.70 percent.

The cost of grow bag filling machine is Rs.49500. The hourly cost of operation for the machine is calculated as Rs.357. The analysis of the results indicated that the performance of the machine was optimum for filling large grow bags at 15 percent moisture content at the ratio S: C: FYM as 1:1:1 for all clearances.