DESIGN AND DEVELOPMENT OF AN AUGER TYPE GROWBAG FILLING SYSTEM

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Theertha M S ***Visna M V*** ***Chetan*** ***Nikhilesh A***

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SYMBOLS AND ABBREVIATIONS

Sl. No.	Abbreviation/Notation		Description
1.	%	:	per cent
2.	et al.	:	and others
3.	/	:	per
4.	i.e.,	:	that is
5.	Fig.	:	Figure
6.	mm	:	millimetre
7.	cm	:	centimetre
8.	m	:	metre
9.	$kg \cdot h^{-1}$	:	kilogram per hour
10.	hp	:	horsepower
11.	*viz.*	:	namely
12.	$g \cdot cm^{-3}$	:	gram per cubic centimetre
13.	$kg \cdot m^{-3}$	:	kilogram per cubic metre
14.	kW	:	kilowatt
15.	kW-h	:	kilowatt-hour
16.	h	:	hour
17.	m^3	:	cubic metre
18.	cm^3	:	cubic centimetre
19.	g	:	gram
20.	kg	:	kilogram
21.	rpm	:	revolutions per minute
22.	$m \cdot s^{-1}$	:	metre per second
23.	µm	:	micrometre
24.	µ	:	micron
25.	$cm^3 \cdot h^{-1}$	:	cubic centimetre per hour
26.	MS	:	Mild Steel
27.	GI	:	Galvanized Iron
28.	VFD	:	Variable Frequency Drive
29.	FYM	:	Farmyard manure

CHAPTER I

INTRODUCTION

Cultivation in growbags is an interesting method of small scale, high yielding agriculture. Preparation of a good quality potting mixture is essential for achieving desirable crop yield. There is an increased demand for potting mixtures for horticultural, plantation and forestry crops nowadays as many people are coming forward interested in agriculture. Moreover, cultivating vegetables in homesteads is getting wider acceptance through various interventions of Government agencies in Kerala. Among the various vegetable growing practices in homesteads, growbag cultivation is the best suited and complementary to urbanisation in the state. It is obvious that, cultivating a crop in an open field is easy and more productive, provided that sufficient land, water and effective crop management practices are made available. In the circumstances of fragmented agricultural lands, homestead cultivation has become inevitable to promote the agriculture for sustainable food production. Fruits, vegetables and ornamental plants are being successfully cultivated in growbags from past few decades in all over the globe to aid the food security. Illegitimate usage of agricultural chemicals to boost the production has resulted in numerous severe health consequences caused by harmful chemical residues. The demand for the safe and organically cultivated agricultural produce has skyrocketed in past decade, although it may not be sustainable for mass production. However, growbag cultivation of vegetables is getting popular nowadays due to the people's initiative to produce safe to eat vegetables at home.

Growbags 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 growbags can be economical as it saves growth medium. Also re-usable and generate very little waste. At the end of the growing season these growbags could rinse and use it again. At the end of the growing season, the used medium provides a very good mulch to spread on the garden. Growbags 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. It can be used in balcony, outside garden, or in a greenhouse. The amount of sunlight and warmth required by the grown plants is also considered while choosing the location. Plants grown in these bags are watered often as it typically require more water than potted plants. There will be a considerable increase in temperature, so keeping the soil moist is essential for growing plants to succeed. Growbags 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 because they will not be stunted by the bottom of the bag. Good choices of vegetable *viz.* tomatoes, peppers (capsicum), eggplants, zucchini, cucumbers, strawberries, French beans, lettuce, potatoes, herbs, and flowers. Hence the growbag cultivation is becoming popular in the State. Also, in the agronomical perspective, the establishment of seedlings in the growbag results good control of pest and disease which results an assured crop yield. For growbag 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 ratio 1:1:1. A potting mix must have ingredients like coir pith so that it retains 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 growbags uniformly is a crucial task. Mixture is only filled to up to $3/4^{th}$ portion of growbags in order to facilitate proper watering. The filling of the mixture in growbags 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 growbag. 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.

In view of the above facts, an auger type power operated growbag filling system was proposed in this study. The main objectives are:

i. To study the physical properties of potting mixture

ii. To design and develop an auger type growbag filling unit

iii. Performance evaluation of the developed growbag filling unit

CHAPTER II

REVIEW OF LITERATURE

The past research works related to growbag filling unit and other parameters are reviewed in this chapter.

2.1 POTTING MIXTURE PROPERTIES

Massey *et al.* (2011) conducted a study on chemical and physical properties of potting media containing varying amounts of composted poultry litter (CPL). A common base mix for woody ornamentals of 8 parts pine bark and 1 part sand was compared with 3 other mixes that contained 20, 40, and 60 per cent compost (v/v), respectively. CPL were analysed to determine the concentrations of nitrogen (organic and soluble), P_2O_5, K_2O, Ca, S, Mg, Mn, Cu, Zn, and Na. The chemical characteristics of the three compost based potting mixes was calculated based on a mass basis. The aeration porosity, total porosity, water holding capacity and bulk density of the four mixes were measured using a chamber that was constructed to facilitate measurement of the physical properties of potting media. The results indicated increasing the percentage of compost in potting media caused the desired decrease in aeration porosity, and total porosity. It was concluded that adding 20 to 40 per cent CPL to a screened bark base mix would provide the majority of the improvements in fertilizer value, physical properties, and mass of water in a container for a growing plant.

Ghehsareh (2015) conducted a test to determine the effect of plant growth on physical properties of potting culture media. The experiment was conducted as factorial in a completely randomized block design with 9 treatments and 3 replications. Treatments included three sizes (S_1 = <0.5, S_2 = 0.5 to 1, and S_3 = 1 to 2 cm) and three composting times (C_1 = 0, C_2 = 3, and C 3 = 6 months) of date palm waste. Statistical analysis showed that the values of bulk density (BD) and water holding capacity (WHC) were significantly increased at the end of cultivation from culture media without plant in comparison to before and after planting ($p<0.05$). Amounts of Ft (total porosity) in culture media without plant were significantly higher than those in culture media before planting and with plant ($p<0.05$). The results of the study showed that composting processes continued in culture media with and without plant, in the meantime, the composting processes were higher in culture media without plant.

Balaji *et al.* (2014) conducted a study on standardization of potting mix. Effect of four different proportions of farmyard manure (FYM) in a soil based mix and three different pot volumes on growth of tomato, eggplant and chilli peppers in paper pots were studied. Recycled newspaper (density 50 g·m^{-3}) was used to prepare pots of volume 45, 82, and 126 cm^3. Potting mixes made up of FYM, sand and soil with the FYM proportion ranging from 20 to 80 per cent in equal proportion of sand and top soil were used. Seedling height and dry weight were measured at the end of the seedling stage. The best combination of potting mix and pot volume for the large scale production of seedlings was identified using non-dominated sorting technique. Paper pots of volume 82 cm^3 filled with a mix of 80 per cent FYM and rest 20 per cent with equal proportions of sand and top soil were found to be the best option for the large scale production of paper pot seedlings.

2.2 GROWBAG FILLING METHODS

Dian *et al.* (2018) developed a semiautomatic plant media bagging machine to reduce the labour required and production lead time during re-planting process. The machine is equipped with hopper to store plant media before it inserted to bag container. Designed hopper can hold up to 250 litres of plant media, which can be used for filling 100 bags. At the hopper also installed an air to assist material flow, this blower work by releasing high pressured air in form of pulse to reduce friction between hopper plate and plant media. Therefore, plant media can transfer to the press tube by using gravity force. The air pulse will repeat every 5 seconds until the press tube is filled with enough plant media. After falling from hopper, plant media will enter a compression tube that used for compressing plant media up to certain density specified by the nursery. Two pneumatic cylinders are used to compress the plant media, one located below the tube to lock and hold plant media where another pneumatic cylinder compress the media from above. The bottom cylinder is equipped with weight sensor which used for weight plant media inside the bag during filling process and monitor the compression force by top cylinder.

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 was uniform growth of seedlings in those containers. Those grown seedlings could be comfortably transplanted manually or mechanically to the ground.

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.

2.3 PERFORMANCE EVALUATION OF GROWBAG FILLING UNIT

Amal (2019) developed and tested potting mixture filling machine to determine its performance and to optimize the machine parameters and material parameters at different moisture contents of 10, 15, 20, 25 and 30 per cent, clearances of 15, 20 and 25 mm, two ratios of soil: coir pith: FYM as 1:1:1 and 1:2:1 mixture and for three bag sizes of small medium and large. Dried soil, coir pith and FYM get pulverized, mixed and filled in the growbags. The properties of growbag mixtures obtained were found out and were on par with the ideal recommendations. The properties such as water holding capacity (165.02%), bulk density (0.493 $g \cdot cm^{-3}$), porosity (65.43 %), fineness modulus (5.31), angle of repose (46.66°), pH (6.76), electrical conductivity (2.19 $dS \cdot m^{-1}$) and uniformity of mixture were observed at the ratio 1:1:1 (S:C:FYM) at the moisture content of 15 per cent. Performance parameters such as weight of bags filled (6.18 kg) time of operation (230 s), capacity of the machine (385 $kg \cdot h^{-1}$), number of bags filled (63) and energy consumption (0.31 kWh for four bags) were obtained with an overall efficiency of 97.70 per cent. The cost of growbag filling machine is Rs. 49,500/-. 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 growbags at 15 per cent moisture content at the ratio S:C:FYM as 1:1:1 for all clearances.

Jayan *et al.* (2017) conducted a study on performance evaluation of KAU Manure Pulverizer. It was tested to determine its performance and into optimize the machine and material parameters. KAU Manure Pulverizer, pulverising the dried goat faecal pellets, neem cake, cow dung etc. Which is getting wide popularity among farmers and is a boon to organic farming of the state. The 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 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.

2.3.1 Screw conveyor

Zareiforoush *et al.* (2010) evaluate the performance characteristics of screw auger. Three screw augers with diameters of 15.5, 20 and 25 cm were evaluated at four conveying angles of 0° (horizontal), 10, 20 and 30° and five rotational speeds of 200, 300, 400, 500 and 600 rpm. The experiments were conducted to a factorial statistical design. The results revealed that with increasing the screw rotational speed, the augers volumetric output increased and reached to a maximum point and after the point, the output started to be decreased. The volumetric output of the augers increased significantly ($P<0.01$) with increasing the auger dimensions. As the conveying inclination of the screw augers increased, the volumetric output and efficiency decreased, significantly ($P<0.01$). The power requirements of the augers increased with increasing the screw rotational speed and conveying inclination ($P<0.01$), while the value found to be deceased with increasing the auger dimensions ($P<0.01$). The investigation concluded that the performance characteristics of screw augers can be affected by the properties of materials being conveyed.

Hemad *et al.* (2010) recent work on screw conveyors performance evaluation during handling process, especially in the case of agricultural grains and bulk materials. Experimental work has been mainly carried out to determine a range of parameters, such as auger dimension, screw rotational speed, screw clearance, conveyor intake length and conveying angle for horizontal, inclined and vertical screw conveyors. Several measurement techniques including theoretical models and DEM have been utilized to study the screw conveyors performance. However, each of these techniques is limited in its application. Difficulties in representing vortex motion and interactions among conveying grains and between the particles and screw rotating flight have so far limited the success of advanced modelling. Hence, more work is needed on screw augers performance to understand and improve the handling process. Research in this area is difficult, but potentially rewarding to enable screw augers to be used effectively in advanced agricultural materials handling and to determine optimum screw design for helical conveying of agricultural materials.

Hemad Zareiforoush *et al.* (2010) evaluated screw conveyor specification in terms of conveyor actual volumetric capacity, volumetric efficiency, specific power and net power requirements. A screw conveyor with the housing diameter of 15.5 cm, screw diameter of 13 cm and screw shaft diameter 3.5 cm having the length of 150 cm was constructed for conducting the experiments. The results revealed that the specific power requirement of the conveyor increased significantly ($P<0.01$) with increasing the screw diametric clearance and screw rotational speed. The net power requirement of the conveyor increased significantly ($P>0.01$) with increasing the screw rotational speed; whilst the value found to be decreased with increasing the screw clearance ($P<0.01$). As the rotational speed of the screw conveyor increased, the actual volumetric capacity increased up to a maximum value and further increases in speed caused a decrease in capacity. The volumetric efficiency of the screw conveyor decreased significantly ($P<0.01$) with increasing the screw diametric clearance and screw rotational speed.

CHAPTER III

MATERIALS AND METHODS

In this chapter, physical properties of potting mixture, methodology adopted for the design, development and performance evaluation of growbag filling unit is briefly explained. Cost analysis of the developed growbag filling unit is also described here.

3.1 PHYSICAL PROPERTIES OF POTTING MIXTURE

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.

3.1.1 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 to 110°C 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,

$$\text{Moisture content, \%} = \frac{[M1-M2]}{M2} \times 100$$

Where,

M_1 : initial weight of the sample, grams

M_2 : final weight of the sample, grams

3.1.2 Bulk density

Bulk density is the ratio of total mass of the mixture and its volume including the pore volume. It is expressed in $g \cdot cm^{-3}$ and was determined using core rings (Ilahi and Ahmed, 2017). Core rings were pushed into the growbag 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.

$$\rho_b = \frac{w_b}{v_b}$$

where,

ρ_b : Bulk density ($g \cdot cm^{-3}$)

W_b : Weight of mixture (g)

V_b : Volume of core ring (cm^3)

3.1.3 Particle density

Particle density is the volumetric mass of the solid growbag mixture. The volume used does not include pore spaces and is expressed in $g \cdot cm^{-3}$. 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).

$$\rho_s = \frac{W_s}{V_s}$$

where,

ρ_s : Particle density, $g.cm^{-3}$

W_s : Weight of dry sample, g

V_s : Volume of sample, cm^3

3.1.4 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,

ρ_b : Bulk density, $g \cdot cm^{-3}$

ρ_s : Particle density, $g \cdot cm^{-3}$

3.1.5 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 2000, 1000, 600, 425 and 300 µm.

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)

3.1.6 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.

3.1.7 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 growbag mixtures. A filter paper was placed in a funnel and a stopper was plugged at the bottom of the funnel. Samples from the growbags 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,

$$WHC, \% = \left(\frac{M_W}{M_S} \times 100\right)$$

where,

WHC : Water holding capacity, %

Mw : Mass of water retained in the sample, g

Ms : Mass of oven dried sample, g

3.1.8 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, degree

h : Height of the cone, cm

d : Diameter of the plate, cm

3.1.9 Proportions of potting mixture

Soil (S), coir pith (C) and farm yard manure (FYM) were used in proportion of 1:1:1 by volume for the preparation of growbag mixture. Evaluation of media prepared helps in determining the best proportion of mix. The effectiveness of the proportions was analysed with respect to moisture content, uniformity, electrical conductivity, pH, water holding capacity, porosity, bulk density, fineness modulus and angle of repose.

3.1.10 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 $dS \cdot m^{-1}$. A COM-80, EC/TDS/Temp hydro tester 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.

3.1.11 Uniformity

Three different dried materials viz., soil, coir pith and farm yard manure 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 growbag 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 growbags 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.

3.2 DESIGN PARAMETERS FOR A GROWBAG FILLING UNIT

3.2.1 Machine parameters affecting growbag filling

3.2.1.1 Conveyor speed

For screw conveyors with screws having regular helical flights all of standard pitch, the conveyor speed may be calculated by the formula:

$$N = \frac{\text{Desired discharge } (cm^3 \cdot h^{-1})}{discharge\ at\ 1\ rpm\ (cm^3 \cdot h^{-1})}$$

Where, 'N' is the conveyor speed i.e., rpm of screw, but not greater than the maximum recommended speed.

For the calculation of conveyor speeds where special types of screws are used, such as short pitch screws, cut flights, cut and folded flights and ribbon flights, an equivalent required capacity must be used.

3.2.1.2 Capacity of screw conveyor

The capacity of a screw conveyor with a standard screw flight.

3.2.1.3 Inclination factor

The inclination factor 'C' is determined by the angle of screw conveyor with the horizontal.

3.2.1.4 Pitch

Pitch (c) is the distance measured parallel to the axis between a point on one screw thread and a corresponding point on the next thread, as shown in Fig. 3.1

3.2.1.5 Shaft diameter

The shaft diameter (d) is defined as the diameter of the hole in the iron laminations, as shown in Fig. 3.1.

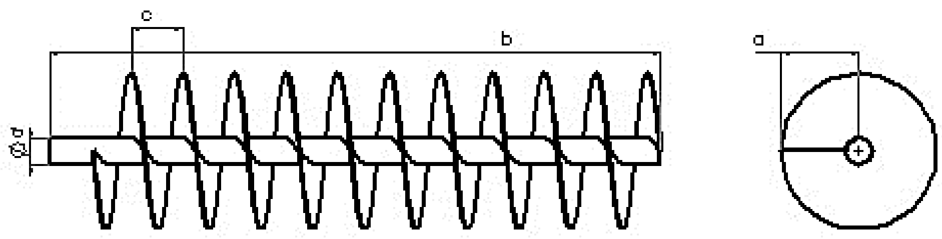


Fig. 3.1 Conceptual 2D drawing of screw conveyor

3.2.2 Design of auger type growbag filling unit

The capacity of the auger (screw conveyor) with a standard screw flight was estimated using the formula,

$$M^{o} = \frac{\pi}{4}(D^2 - d^2) \times P \times N \times \alpha \times \rho \times C \times 60$$

Where,

M^{o}	: Screw capacity, kg·h^{-1}
D	: Screw diameter, m
P	: Screw pitch, m
N	: Screw speed, rpm
α	: Loading ratio
ρ	: Material loose density, kg·m^{-3}
C	: Inclination correction factor

Step 1: Establish the conveying requirement

In order to meet the functional requirements of a conveyor, it is important to consider certain design parameters influencing the intended application; those are as follows:

i. Type of material to be conveyed
ii. Required flow (kilograms per hour or cubic metre per hour)
iii. Distance the material will be conveyed to

Step 2: Calculation of the capacity of the auger

Theoretical pitch volume of screw conveyor, V_{th} (cm^3) = $\frac{\pi}{4}(D^2 - d^2) \times P$

Estimate the loading ratio α of the screw according to the flow properties of the solid to be conveyed.

Table 3.1 Loading ratios of materials

Material		Loading ratio	
		Minimum	Maximum
i.	Not free flowing	0.12	0.15
ii.	Average flowability	0.25	0.30
iii.	Free flowing	0.40	0.45

Table 3.2 Inclination and corresponding correction factor

Inclination, °	Correction factor, C
0	1.00
5	0.90
10	0.80
15	0.70
20	0.65

For inclined screw conveyor design: Define if the screw conveyor is flat (which is always preferable) or has to be inclined. Determine the correction factor corresponding.

Adjust the screw speed so that the capacity of the screw is higher than the requirement.

$$M^o = \frac{\pi}{4}(D^2 - d^2) \times P \times N \times \alpha \times \rho \times C \times 60$$

Where,

M^o : Mass capacity or mass flow rate of the auger (screw conveyor), $kg{\cdot}h^{-1}$
D : Screw diameter, m
D : Shaft diameter, m
P : Screw pitch, m
N : Screw speed, rpm
α : Loading ratio
ρ : Material loose density, $kg{\cdot}m^{-3}$
C : Inclination correction factor

For different rpms the capacity is calculated.

Step 3: Compare the calculated capacity to the maximum screw speed

Reference for max screw speed are given in the table below:

Table 3.3 Auger diameters with different load

Sl. No.	Auger diameter, m	Load, %		
		15	**30**	**45**
i.	0.10	69	139	190
ii.	0.15	66	132	182
iii.	0.23	62	122	170
iv.	0.25	60	118	165
v.	0.30	58	111	157
vi.	0.36	56	104	148
vii.	0.41	53	97	140
viii.	0.46	50	90	131
ix.	0.51	47	82	122
x.	0.61	42	68	105

If the calculated speed at step 2 is less than the maximum speed for the auger diameter selected, the design can be kept.

If the calculated speed at step 2 is greater than the maximum speed for the auger diameter selected, the design is not suitable and the calculation must be run again by changing a parameter, typically the diameter.

3.2.2.1 Screw Auger

A screw conveyor or auger conveyor is a mechanism that uses a rotating helical screw blade, called a flighting, usually within a tube, to move liquid or granular materials. These type of augers are used in many bulk handling industries.

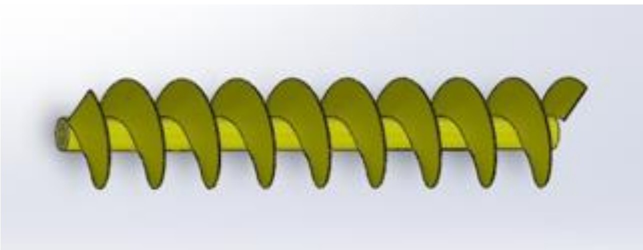


Fig. 3.2 Conceptual 3D drawing of Screw auger

3.2.3 Power

Power requirement of screw feeder basically depends on the length of screw conveyor, capacity and a factor for total apparent resistance. This resistance varies with respect to type of material conveyed that is its nature, abrasiveness, grain size, internal resistance etc. One of the method for calculation of power requirements of screw feeder is given below (that we have used) (from IS 12960:1990)

Drive power requirement of a loaded screw, $P = P_H + P_N + P_{St}$

Where,

P_H : power necessary for the progress of the material, kW

P_N : drive power of the screw feeder at no load, kW

P_{St} : power due to inclination, kW

$$P_H = \frac{I_m L \lambda}{367}$$

where,

I_m : mass flow rate, t/h

$$I_m = \rho I_v$$

L : conveying length, m

λ : Progress resistance coefficient

Each material has its own coefficient λ it is generally in the order of 2 to 4.

$$P_N = \frac{DL}{20}$$

Where,

D : nominal screw diameter, m

$$P_{St} = \frac{I_m H}{367}$$

Where,

H : lifting height, m

3.2.4 Belt selection

Table 3.4 Data on standard v-belt sections

Cross-section symbol	Usual load of drive, kW	Recommended minimum pulley pitch diameter d, mm	Nominal top width W, mm	Nominal thickness T, mm	Weight per metre, kgf
A	0.75-5	75	13	8	0.106
B	2-15	125	17	11	0.189
C	7.5-75	200	22	14	0.343
D	22-150	355	32	19	0.596
E	30-190	500	38	23	-

Appropriate belt could be selected according to the power required and the size of the pulley.

3.2.5 Shaft design

Shaft was designed according to the power to be transmitted and bending and torsional moment. The design procedures are discussed below:

$$\text{Diameter of coupling shaft, } D^3 = \frac{16}{\pi \times \tau} \times \sqrt{(K_b \cdot \mathrm{M})^2 + (K_t \cdot \mathrm{T})^2}$$

where,

τ : Shear stress, MPa

K_b : Combined shock and fatigue factor for bending moment

M : Bending moment, N·m

K_t : Combined shock and fatigue factor for torsional moment

T : Torsional moment, N·m

The values of K_b and K_t are taken from the table below.

Table 3.5 Combined shock and fatigue factor for bending and torsional moment

Type	K_b	K_t
A. Stationary shaft		
i. Gradually applied load	1.0	1.0
ii. Suddenly applied load	1.5-2.0	1.5-2.0
B. Revolving shaft		
i. Gradual loading	1.5	1.0
ii. Minor shock loads	1.5-2.0	1.0-1.5
iii. Heavy shock loads	2.0-3.0	1.5-3.0

Bending moment, $M = (T_1 + T_2 + 2 \cdot T_c) \times$ Overhung distance $\times$ No. of belts

where,

T_1 : Tension in the tight side of the belt, N

T_2 : Tension in the slack side of the belt, N

T_c : Centrifugal tension,

$$\frac{T_1}{T_2} = e^{\mu\theta \times \operatorname{cosec}\beta}$$

where,

μ : Coefficient of friction between belt and pulley

2β : Angle of groove on the pulley, degree

θ : Angle of lap, degree

Centrifugal tension, $T_c = m \cdot v^2$

where,

m : mass of the belt, kg·m

v : velocity of the pulley, $m \cdot s^{-1}$

Torque transmitted by the driven pulley shaft, $T = \frac{P \times 60}{2\pi N_1}$

where,

P : Power, watts

N_1 : Speed of driven pulley

Power, $P = (T_1 - T_2) \times v$

3.2.6 Material properties

When designing a screw conveyor, special considerations must be given to the selection of components if the material conveyed has unusual characteristics. The following information are discussed below.

3.2.6.1 Abrasiveness

Abrasive materials can cause excessive wear on conveyor components. It should be carried at lower speeds and at lower trough loads. For very abrasive materials, it may be necessary to use thicker flights and troughs, surface hardeners or special alloy components.

3.2.6.2 Contamination

Contaminable materials, such as certain chemicals and food additives, require the use of sealed end bearings and hanger bearings of wood, nylon or other dry operating type. Trough covers should be tightly sealed and easily removable for frequent cleaning and all the internal welds that contact the material may require polishing to eliminate material entrapment.

3.2.6.3 Degradability

Materials that tend to break up or separate should be carried in large diameter conveyors at very slow speeds to minimize physical agitation of the material.

3.2.6.4 Temperature

Conveyors moving materials at extreme temperatures should be constructed of metal alloys designed to meet such conditions. Highly corrosive materials, combined with high temperatures, require special attention to construction alloys to maximize component life. The use of jacketed troughs may be advisable, wherein a heating or cooling medium may be circulated to keep the conveyed material within safe operating temperatures. Conveyors handling hot materials also experience thermal expansion and may increase in length as the temperature of the trough and screw increases when the hot material begins to be conveyed.

3.2.6.5 Explosiveness

The conveyor must be designed with non-sparking and explosion-proof components and must be tightly sealed. Where hazardous dust and fumes exist, an active exhaust system may be provided for proper venting.

3.2.6.6 Fluidization

When conveying materials that tend to aerate and increase in volume, the conveyor size and speed must be designed on the basis of this larger aerated volume and density. Such materials will often flow through the clearances around the flights. Slow speeds, low clearances and special flight edging will help.

3.2.6.7 Hygroscopic nature

Hygroscopic materials readily absorb moisture and tend to become denser and less free flowing. This must be taken into account when designing the size, speed, and power requirement of the conveyor. Tightly sealed conveyors that exclude exterior atmosphere are desirable in handling such materials.

3.2.6.8 Mixing

When mixing or blending of materials is required, a conveyor screw consisting of ribbon flighting, cut and folded flighting, cut flighting or paddles may be used alone or in any combination to obtain the desired results.

3.2.6.9 Inclination

Inclined screw conveyors have a greater power requirement and lower capacity rating compared to horizontal conveyors. The power requirement increases and capacity decreases depends on the angle of inclination and the characteristics of the material being conveyed.

3.3 INSTRUMENTATION AND SOFTWARE USED

3.3.1 Variable frequency drive (VFD) for conveyor speed control

A variable-frequency drive (VFD) is a type of motor drive used in electro mechanical drive systems to control AC motor speed and torque by varying motor input frequency and, depending on topology, to control associated voltage or current variation. VFDs are used in applications ranging from small appliances to large compressors.

Specifications:

Make	: M/s. ABB India Ltd.
Model	: IP20/UL Open type
PN	: 2.2 kW (3 HP)
U1	: 3~ 400 V/480 V
I1	: 9.6 A/ 8.0 A
f1	: 48 to 63 Hz

Plate 3.1 Variable frequency drive

3.3.2 Tachometer

Tachometer is an instrument measuring the rotational speed of a shaft or disk, as in a motor or other machine. The analog device usually displays the revolutions per minute (rpm) on a calibrated dial, however digital displays are common nowadays. The specifications of the digital contact/non-contact tachometer used were as follows:

Make	: M/s. Systems and Controls, Bangalore (India)
Model	: HTM – 890
Display	: 5 Digits, 7 Segment bright red LED.
Range	: 0 to 99,999 rpm Photo and Contact Tach.

Plate 3.2 Tachometer

3.3.3 Software

The computer-aided design (CAD) software SOLIDWORKS® 2022 was used for designing and conceptualizing the models during the various stages of the research work. SolidWorks is a solid modelling CAD and computer-aided engineering (CAE) software that runs on Microsoft Windows platform. It offers complete 2D and 3D software tools in order to create, simulate, publish, and manage the geometric data. The user interface of the software is illustrated in Plate. 3.3.

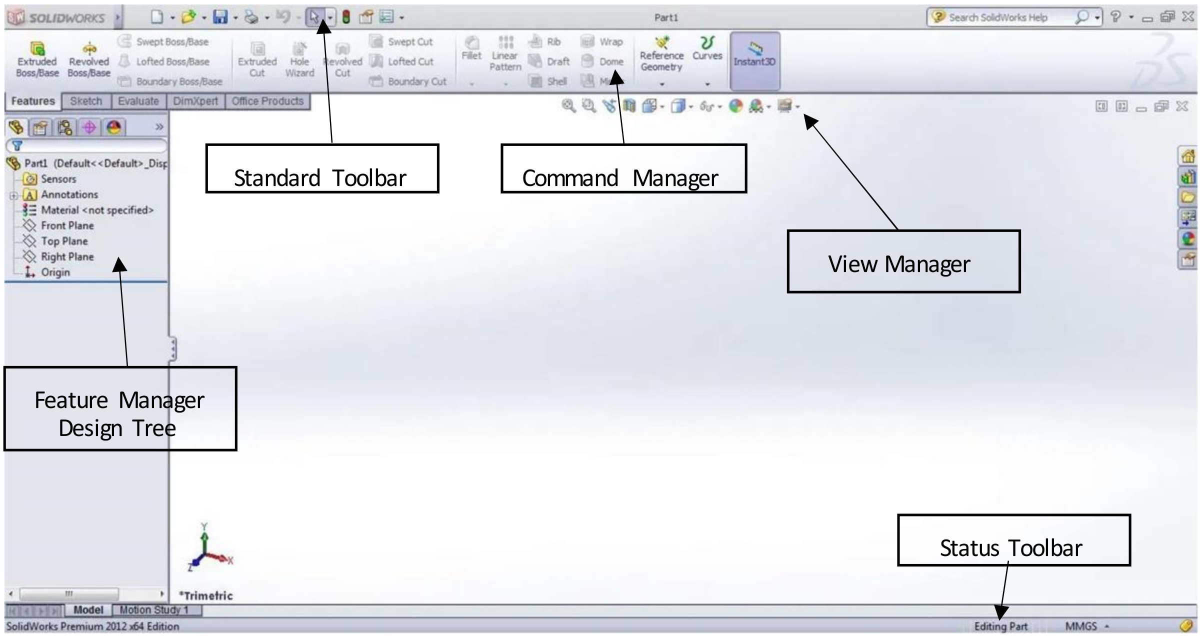


Plate 3.3 User interface of SOLIDWORKS

3.4 PERFORMANCE EVALUATION

The performance evaluation of the developed unit was conducted by analysing various operational parameters such as weights of bags filled, time for filling bags, and capacity of the unit, number of bags filled, energy consumption and efficiency of the unit. The methods followed for the same are described below.

3.4.1 Types of growbags

Three types of growbags were selected for the performance evaluation of the developed unit. It includes small, medium and large type growbags with size of 16×16×30, 20×20×35 and 24×24×40 cm respectively. The material was dual layer Low Density Poly-Ethylene (LDPE) with the thickness of 150 microns, 600 gauge. These bags were Ultraviolet (UV) stabilized with outside white and inside black in colour.

3.4.2 Percentage variation

It is the ratio of difference between the actual and estimated discharge to the estimated discharge.

$$\text{Percentage variation} = \left(\frac{Actual\ discharge - Estimated\ discharge}{Estimated\ discharge}\right) \times 100$$

3.4.3 Time for filling

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

3.4.4 Capacity of the unit

Capacity of the unit was calculated as the amount of growbag mixture obtained at the outlet per unit time. Growbag 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,

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

3.4.5 Efficiency of the filling unit

Efficiency of the unit is the ratio of actual capacity to theoretical capacity. Efficiency was calculated at different moisture contents of the materials.

$$\text{Efficiency, \%} = \frac{\text{Actual capacity}}{\text{Theoretical capacity}} \times 100$$

3.5 COST ESTIMATION

It is necessary to consider the cost analysis of growbag filling unit during its design and development. The main objective is to make the analysis of rates economically feasible. The cost estimation mainly includes the determination of analysis of rates of each material and the estimation of total cost. Analysis of rates includes the estimation of quantity of item used and cost of materials per unit. Total cost is estimated by multiplying the cost per unit with quantity of the item used.

$$\text{Total cost (Rs.)} = \text{Rate of material} \times \text{Quantity of material used}$$

Labour charges and miscellaneous charges are also included in the cost estimation. In the cost estimation of growbag filling unit, the miscellaneous charge is taken as 3 per cent of total cost obtained. Grand total amount is obtained by adding this miscellaneous charge with total cost.

Machinery Costs

Farm machinery costs can be divided into two categories:

i. Annual ownership costs i.e. Fixed cost, which occur regardless of machine use
ii. Operating costs, which vary directly with the amount of machine use.

The true value of some of these costs is not known until the machine is sold or worn out. But the costs can be estimated by making a few assumptions about machine life, annual use, and fuel and labour prices.

3.5.1 Fixed cost / Ownership cost

Include depreciation, interest (opportunity cost), taxes, insurance, and housing facilities. It is the total cost of all materials required for construction considering the depreciation cost.

3.5.1.1 Depreciation

Depreciation is a cost resulting from wear, obsolescence, and age of a machine. The degree of mechanical wear may cause the value of a particular machine to be somewhat above or below the average value for similar machines when it is traded or sold.

$$\text{Depreciation (D)} = \frac{P-S}{L \times H}$$

Where,

D : Average annual depreciation, $Rs \cdot h^{-1}$

P : Purchase price, Rs.

S : Salvage value, taken as 10 per cent of the purchase price

L : Life of machine, years

H : Annual use of machine, hours

3.5.1.2 Interest

If the operator borrows money to buy a machine, the lender will determine the interest rate to charge.

3.5.1.3 Taxes and Insurance

This cost usually is much smaller than depreciation and interest, but they need to be considered. A cost estimate equal to 1.0 per cent of the purchase price often is used.

3.5.1.4 Housing

Providing shelter, tools, and maintenance equipment for machinery will result in fewer repairs in the field and less deterioration of mechanical parts and appearance from weathering. That should produce greater reliability in the field and a higher trade-in value. An estimated charge of 1.0 per cent of the purchase price is suggested for housing costs.

3.5.2 Operational cost

It is also called as the variable costs. It varies in proportion to the amount of machine. The operating cost consists of labour charges, lubrication, energy consumed and repair and maintenance cost (1 to 2 %).

$$\text{Cost of energy consumption} = \text{energy consumed} \times \text{unit rate of electricity}$$

3.5.2.1 Energy consumption

It is the amount of electrical energy consumed by the unit for filling growbags in one hour. A three-phase AC wattmeter with 300 to 600 V, 10 to 20 A and 50 Hz rated voltage, current and frequency respectively was used for the energy measurement. It was connected to the terminals of the unit and the number of revolutions were recorded for each type of bags. Electrical energy consumed was calculated using the equation,

$$\text{Energy consumed (kWh)} = \text{Power} \times \text{Time}$$

3.5.3 Total Cost

After all costs have been estimated, the total ownership cost per hour can be added to the operating cost per hour to calculate total cost per hour to own and operate the machine.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter includes the physical properties of the selected material, development of growbag filling unit, the results of performance evaluation of the developed unit. The overall performance of the unit was also evaluated with respect to weight of bags filled, capacity of the unit, efficiency, time and energy consumption. It also considers the details and specifications of the developed auger type growbag filling unit and cost analysis.

4.1 PHYSICAL PROPERTIES OF THE MATERIAL SELECTED

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. Soil (S), coir pith (C) and cow dung (FYM) were mixed used in one proportion by volume for the preparation of potting mixture S:C:FYM as 1:1:1.

4.1.1 Moisture content

Soil water is the major component of the soil in relation to plant growth. If the moisture content of a soil is optimum for plant growth, plants can readily absorb soil water. Moisture content of 1:1:1 (S:C:FYM) potting mixture was analysed and are given in Appendix II. The value of moisture content obtained as 15 per cent.

4.1.2 Bulk density

Bulk density is an important factor in growbag 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 growbag mixtures to facilitate proper anchorage to the plants grown. Bulk density of 1:1:1 (S:C:FYM) potting mixture was analysed and are given in Appendix II. The values of bulk density obtained as 1.11 $g \cdot cm^{-3}$.

4.1.3 Particle density

Particle density is another important factor for selecting the potting mixture. Particle density was obtained as 1.47 $g \cdot cm^{-3}$ for 1:1:1 (S:C:FYM) potting mixture.

4.1.4 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. The value of porosity of mixture was analysed and are given in Appendix II. In the 1:1:1 ratio, porosity is 24.49 per cent.

4.1.5 Fineness module

Fineness modulus of mixture, was determined by sieve analysis and corresponding values are given in Appendix II. It is obtained as 5.45 for the ratio of 1:1:1. More fine powder was obtained when the materials were dry. It may aid in easy intake of nutrients by the plants.

4.1.6 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 the potting mixture for different moisture contents, were analysed and are given in Appendix II. It obtained as 6.74 at the ratio of 1:1:1. The value of pH was found to be lower than the neutral value (slightly acidic) at the ratio of 1:1:1. it is due to high volume of coir pith with acidic nature.

4.1.7 Angle of repose

Angle of repose plays an important role in the design of hoppers. Angle of repose of mixture varied with the changes in moisture content and proportion of mixture. The effect of moisture content, and ratio of mixture were analysed for angle of repose and are given in Appendix II. It varied between 45.23° and 46.11° at the ratio of 1:1:1. Angle of repose attained higher values for the fine mixture and angle of repose increases with the decrease in particle size of powder (Carstensen and Chan, 1976).

4.1.8 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 were analysed and are presented in Appendix II. It varied from 2.05 to 2.17 $dS \cdot m^{-1}$ at the ratio of 1:1:1. The effect due to moisture was significant on electrical conductivity.

4.1.9 Uniformity

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 analysed and are reported in Appendix II. A maximum percentage deviation of 2.05 per cent was recorded at the ratio 1:1:1. Change in moisture 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 growbag mixture is filled uniformly by using the newly developed machine.

4.1.10 Proportion of potting mixture

Soil (S), coir pith (C) and farm yard manure were used in the proportion 1:1:1 by volume. The effectiveness of the proportion was analysed. Bulk density, particle density, porosity, pH, angle of repose, electrical conductivity, uniformity and fineness modulus were found to be 1.11 $g \cdot cm^{-3}$, 1.47 $g \cdot cm^{-3}$, 24.49 per cent, 6.5 and 6.8, 43.24° and 57.00°, 1.99 to 2.71 $dS \cdot m^{-1}$, 4.17 per cent (deviation), and 5.13 respectively.

4.2 DEVELOPMENT OF GROWBAG FILLING UNIT

An auger type growbag filling unit suitable for filling potting mixture in growbags of different sizes using designed values was developed.

4.2.1 Power

The drive power of the loaded screw is given by the formula,

$$P = P_H + P_N + P_{St}$$

Where,

P_H : Power necessary for the progress of the material, kW

P_N : Drive power of the screw feeder at no load, kW

P_{St} : Power due to inclination, kW

Since, screw is aligned horizontally in order to reduce load on screw and thus increasing discharge, power due to inclination (P_{St}) was taken zero.

The power requirement of the unit was calculated to be 0.0386 hp. (Appendix I)

4.2.2 Belt selection

The belts are meant for power transmission, so power requirement of the unit is to be considered while selecting the belt. According to the table 3.4 design diameter for the power requirement of 0.75 kW to 5 kW series '**A**' type v-belts are recommended. The specifications of the selected belt were,

V-belt Size : A38

Cross-section : 13 (width) and 8 (thickness) mm

4.2.3 Shaft design

A coupling shaft was selected. A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both.

Shaft was designed to transmit a power of 30 W under a bending moment of 3.553 N·m and torsional moment of 2.204 N·m, then the required diameter was found to be 10 mm.

4.2.4 Components

The components of developed auger type growbag filling unit are main frame, hopper, screw auger, screw auger casing, outlet, driving pulley, driven pulley, belt, pedal switch, nuts and bolts, Plummer block and prime mover.

4.2.4.1 Main frame

The main frame is the structural component on which operational components are mounted. The materials used for fabrication are mild steel (MS) angle, flat, plate, rod and galvanized iron (GI) square pipe. A suitable structure was designed in CAD and fabricated to the design dimensions. In order to fix the screw auger, four MS angles were welded using electric arc welding to the frame at a height of 890 mm from ground level.

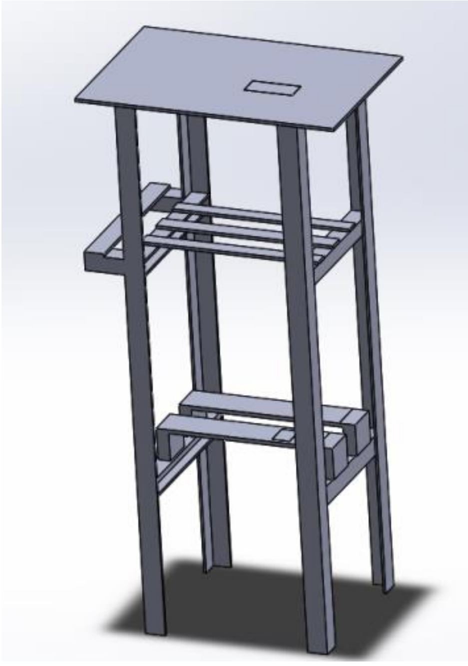


Fig. 4.1 3D model of main frame

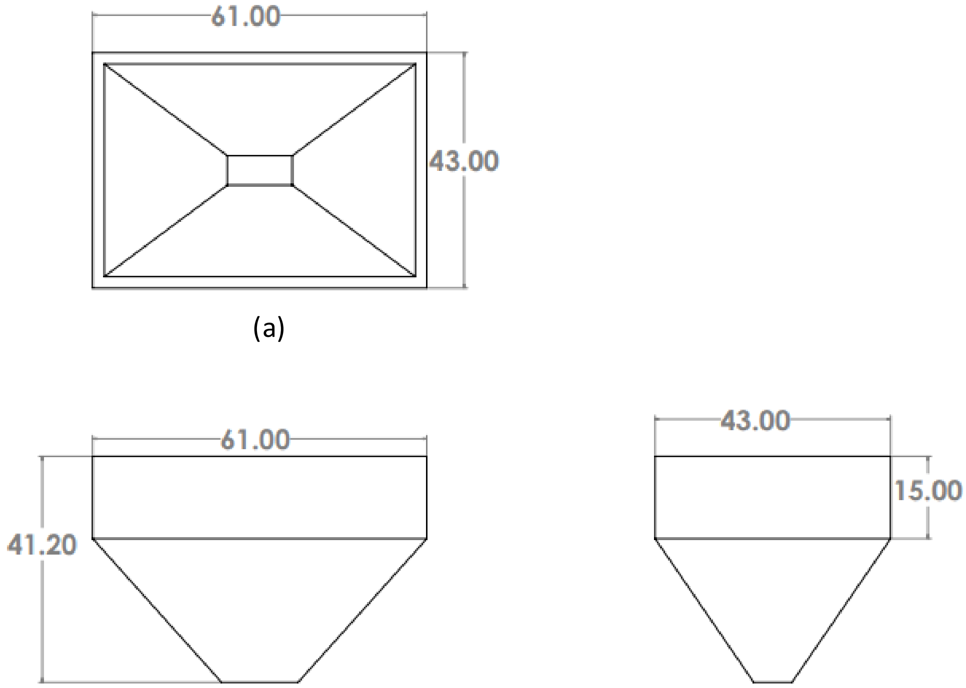
4.2.4.2 Prime mover

A three phase electric motor having 1.0 hp with 1380 rpm, 415 V, 2.8 A and 50 Hz rated speed, voltage, current and frequency respectively was used as prime mover for conveying the potting mixture. The motor consist of three main components-the stator, the rotor, and the enclosure. Power transmission done through pulley and V-belt system.

Plate 4.1 Prime mover

4.2.4.3 Hopper

The mixture of dried soil, coir pith and dried manures were fed manually through the feeding hopper to the screw auger. The feeding chute was trapezoidal in shape having 610 mm top length, 430 mm top width, 145 mm bottom length and 70mm bottom width. It was made of a MS plate of thickness 6 mm having a total height of 410 mm.



(a) (b) (c)

Fig. 4.2 3D model of hopper (a) Top view, (b) Front view and (c) Side view

4.2.4.4 Screw auger

A screw conveyor or auger conveyor is a mechanism that uses a rotating helical screw blade, usually within a tube, to move granular materials. Here the potting mixture is transferred through horizontal screw conveyor. Made of Stainless steel with a diameter of 9.5 cm. And the pitch is 2.54 cm.

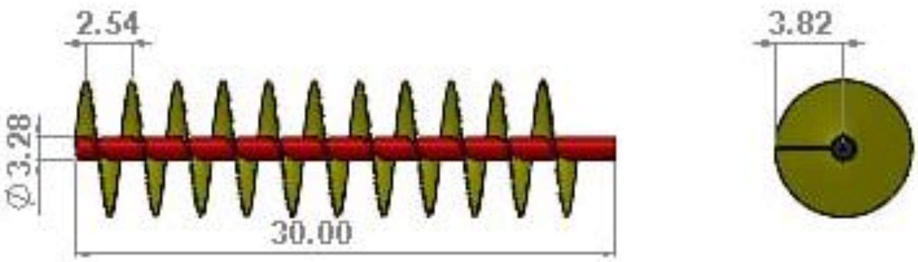


Fig. 4.3 3D model of screw auger

4.2.4.5 Screw auger casing

Screw casing give the protection for the screw auger. Screw casing designed on the basis of screw auger diameter. A clearance is provided between the screw auger and its casing. Cylindrical casing with diameter of 10.18 cm and a length of 35 cm is fabricated. GI sheet is used.

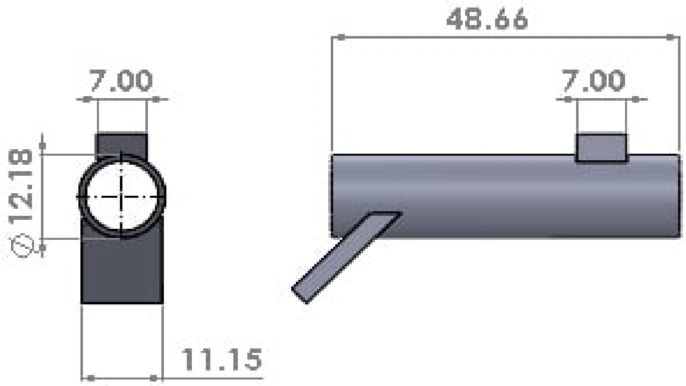


Fig. 4.4 3D model of screw casing

4.2.4.6 Outlet

Outlet of the screw auger is provided at the right bottom corner. And the outlet is designed based on the discharge of the screw auger.

4.2.4.7 Driving pulley

Driving pulley is attached to the motor, used for power transmission. The driving pulley transmits power to the driven pulley through a v-belt. Diameter of the driving pulley was selected as 7.8 cm.

4.2.4.8 Driven pulley

The driven pulley mounted on screw shaft receives the power from the driving pulley, which then in turn rotates the screw auger. The speed of the driven pulley can be adjusted by the driving-driven pulley diameter ratio. Diameter of the driven pulley was selected 15.8 cm.

Plate 4.2 Belt-Pulley system

4.2.4.9 Belt

Speed reduction is achieved by the larger driving pulley and smaller driven pulley linked through a v-belt. Belt is selected according to the size of driving and driven pulley. A v-belt of size A38 was selected for the power transmission.

4.2.4.10 Pedal switch

A pedal switch was provided to control the operation of the developed unit.

4.2.4.11 Nuts and bolts

Hexagonal nut and bolts of size of M10 were used as the hardware fasteners.

4.2.4.12 Plummer block

Plummer block gives friction free smooth rotation of the shaft. The casing is made of cast iron and bearing from chrome steel. Two plummer blocks are used in the developed growbag filling unit. It is a pedestal used to provide support for a rotating shaft with help of compatible bearings and other accessories. The bearing blocks are bolted with frame. Designation number represents the different dimensions of the plummer blocks used in auger type growbag filling unit. The bearing number UC205 was used for friction free rotation of the screw. The selected plummer block is shown in Plate 3.10.

Plate 4.3 Plummer block

4.2.5 Working principle

The mechanism involved in growbag filling unit and its working principle are described in the following sections.

4.2.5.1 Motion transmission by pulley and V-belt arrangement

In a belt and pulley system, belt runs along the groove and connects one pulley to the next. The speed can be adjusted using the speed reduction ratio. Pulley and belt system is used to transmit the rotational motion. The driven pulley (small, ϕ7.8 cm) attached to the prime mover. The driving pulley (large, ϕ15.8 cm) drives the driven pulley with the help of the belt. Using variable frequency drive (VFD) we can control the speed of prime mover, and the controlled speed is transmitted to the driving pulley. The speed is again gets reduced by belt and driven pulley system.

4.2.5.2 Screw conveyor

A screw conveyor or auger conveyor is a mechanism that uses a rotating helical screw blade, called a ‘flighting’, usually within a tube, to move liquid or granular materials. They are used in many bulk handling industries. When screw conveyor works, the screw shaft rotates, and the material moves forward in the horizontal direction along trough bottom of the conveyor under the push of the blade.

When the prime mover works and fed the potting mixture through the hopper. The pitch of the screw auger filled with the mixture, when the blade rotates the material is conveyed to the outlet and fill the growbags.

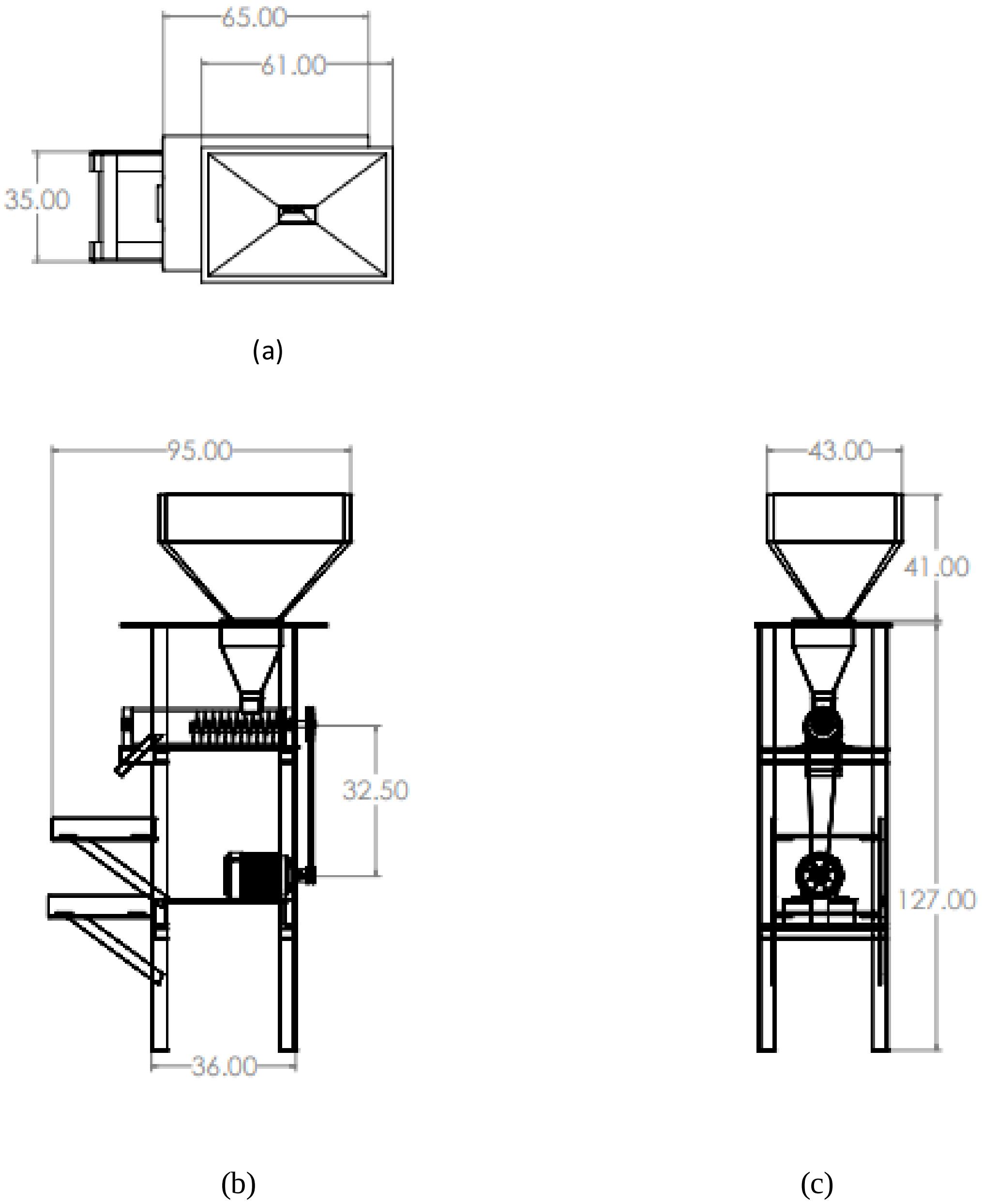


Fig.4.5: Model of growbag filling unit (a) Top view, (b) Front view and (c) Side view

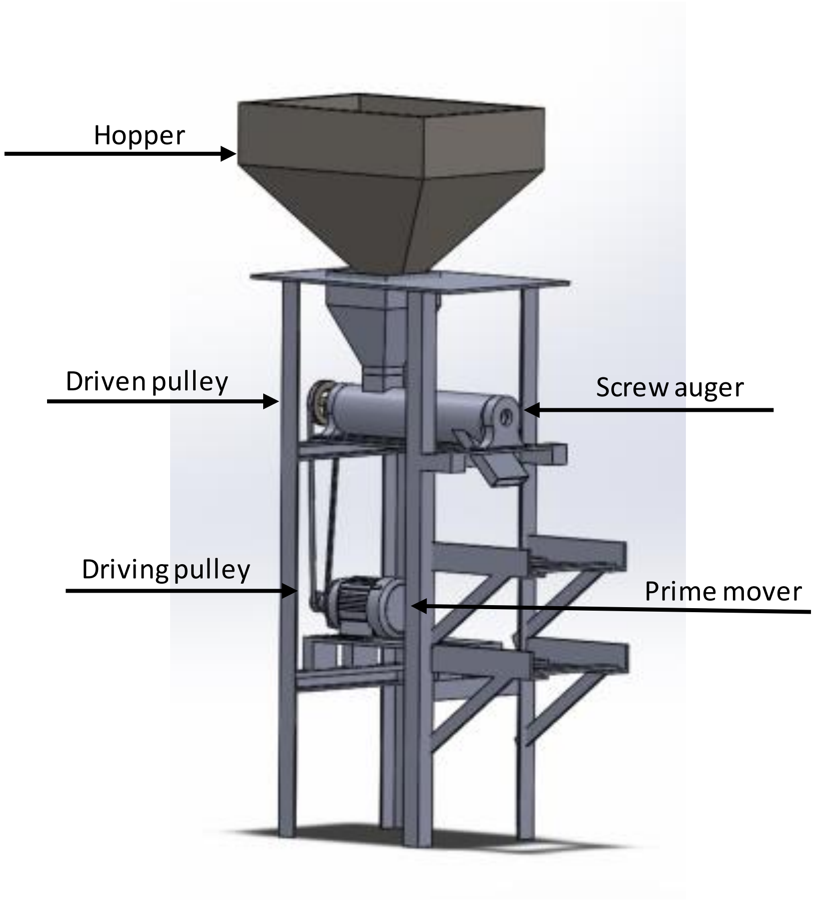


Fig.4.6: Growbag filling unit

4.2.5.3 Working of growbag filling unit

The speed (rpm) of the motor was controlled using a VFD. The power transmission and speed reduction was achieved using belt-pulley mechanism, keeping the diameter of driven pulley is greater than the diameter of driving pulley on the drive motor shaft.

When the pedal switch is pressed, drive motor is energized and the power is transmitted to the shaft of screw auger through the v-belt pulley. The potting mixture is discharged through the outlet. When the pedal switch is released the electrical power supply to the drive motor is cut off and the operation of the unit halts.

Plate 4.4 Growbag filling unit

4.3 PERFORMANCE EVALUATION

4.3.1 Weight of bags filled

Growbags are usually filled to the three-fourth of its volume to avoid spillage during handling and irrigation. Smaller growbags are preferred to facilitate easy handling and subsequent growth stages of the plant. Weight of filled growbags is affected by change in bulk densities which depends on the moisture content of the potting mixture.

The average weights 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 growbags varied between 3.93 and 4.45 kg and between 4.09 and 4.59 kg at 1:1:1 and 1:2:1 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 6.01 and 6.76 kg for 1:0.5:1 ratio. Weights of three types of growbag mixtures increased with the increase in moisture content of the materials. The weights of three different growbag sizes after filling the potting mixture (at moisture content 10 to 15%) were observed as follows:

i. Small : 2.4 kg
ii. Medium : 4.5 kg
iii. Large : 6.5 kg

4.3.2 Time taken for filling growbags

Time for filling the small, medium and large growbags were different. It is an important parameter for calculating the performance of the developed unit. It has a direct impact on capacity of the unit. Time of filling increased with the increase in moisture content of the materials for all types of bags. Time taken for filling of small, medium and large growbag is 21, 39 and 57 seconds respectively. (Appendix III)

4.3.3 Capacity of the growbag filling unit

Capacity of the growbag filling unit was calculated as the total quantity of materials filled in growbags in an hour at its filling efficiency. It is considered as an important parameter for the performance evaluation of the unit. It differed for varying sizes of growbags. 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. Capacity of the unit varied between 286.87 to 478.12 kg·h^{-1} with different speed of the screw conveyor. (Appendix III)

Table 4.1 Capacity of screw conveyor with different speed

Screw conveyor speed, rpm		Capacity of screw conveyor, kg·h^{-1}
i.	90	286.87
ii.	100	318.74
iii.	110	350.62
iv.	120	382.49
v.	**130**	**414.37**
vi.	140	446.24
vii.	150	478.12

- Capacity of 414.37 kg·h^{-1} was selected (see Table 3.3).
- The screw diameter selected was 0.1 m for which the max screw speed at 30 per cent is advised to be 139 rpm.
- If the calculated speed is less than the max speed for the screw diameter selected, the design can be kept.
- If the calculated speed is too high, the calculation must be done by changing a parameter. We can select a diameter larger, D = 0.15 m

- If the calculated speed is greater than the max speed for the screw diameter selected, the design is not suitable and the calculation must be run again by changing a parameter, typically the diameter.

4.3.4 Number of bags filled per unit time

Capacity of the unit is also calculated based on the number of growbags filled in one hour. More time of filling was recorded for large growbags followed by medium and small bags. The number of bags filled in an hour varied in the range 63 to 172. (Appendix III)

Table 4.2 Number of bags filled per unit time for different sized bag

Type of growbag		Filling capacity, kg	No. of bags filled per hour
i.	Small	2.5	172
ii.	Medium	4.5	92
iii.	Large	6.5	63

4.3.5 Effect of speed of screw conveyor on percentage screw load

With the increase in speed of screw conveyor (rpm), the percentage load in the screw was reduced.

Table 4.3 Percentage screw load on the screw for different rpms

Sl. No.	Speed of screw conveyor, rpm	Percentage screw load, %
1.	50	33.76
2.	60	31.05
3.	70	35.49
4.	80	35.98
5.	90	33.46
6.	100	31.37
7.	110	28.23
8.	120	28.20
9.	130	23.53
10.	140	20.10
11.	150	20.50

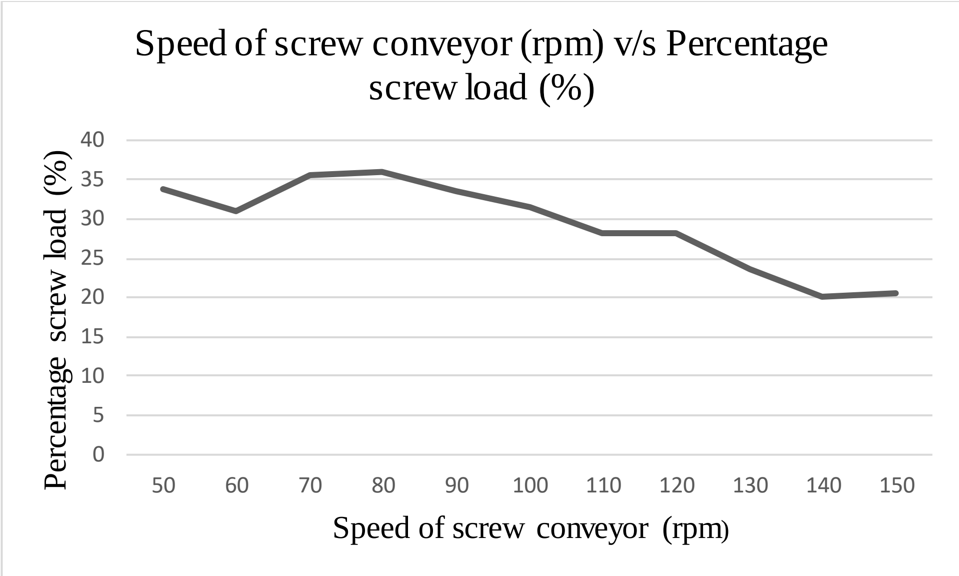


Fig. 4.7 Relationship between speed of screw conveyor (rpm) and screw load (%)

4.3.6 Efficiency of the developed growbag filling unit

Efficiency of the developed growbag filling unit is calculated as the ratio of actual capacity to theoretical capacity. The capacity of the unit was found to be 414.37 kg·h^{-1} when no bags were placed.

Table 4.4 Efficiency of growbag filling unit for different moisture content

Sl. No.	Moisture content, %	Efficiency, %
1.	10	96.50
2.	15	97.70
3.	20	95.38
4.	25	94.61
5.	30	92.69

4.3.7 Percentage variation

Table 4.5 Percentage variation with respect to discharge.

Actual discharge	Estimated discharge	Percentage variation, %	Modulus of percentage variation, %
4.80	4.50	6.67	6.67
4.20	4.50	-6.67	6.67
4.45	4.50	-1.11	1.11
4.60	4.50	2.22	2.22

4.33	4.50	-3.78	3.78
4.66	4.50	3.56	3.56
4.75	4.50	5.56	5.56
4.78	4.50	6.22	6.22
		Average	**4.47**

4.4 COST ESTIMATION

The analysis of rates and the cost estimation is done in order to evaluate the economic feasibility of the developed auger type growbag filling unit. The estimated total cost for the fabrication of auger type growbag filling unit was found to be Rs. 19,759/-. The total cost included the cost of fabrication of all components of the growbag filling unit as well as the painting and labour charges. By considering miscellaneous cost as 3 per cent of auger type growbag filling unit, the grand total for the fabrication cost of auger type growbag filling unit was determined as Rs. 20,352/-. Operational cost was found to be around Rs. 140/- per hour. (Appendix IV)

4.4.1 Energy consumption

The energy consumed by the unit was calculated by multiplying power with time. Time is taken as 1 hour. Power required by the growbag filling unit was calculated as 0.0289 kW. Energy consumed by the unit was found to be 0.0289 kWh.

CHAPTER V

SUMMARY AND CONCLUSION

Agricultural land is reduced due to land degradation, erosion or being converted for other purposes, to overcome this constraints growbag cultivation is introduced. Cultivation in growbags is an interesting method of small scale, high yielding agriculture. Growbags filled with sand, coir pith and farmyard manure in the ratio of 1:1:1. Growbag filling is a time consuming and laborious process. The auger type growbag filling unit serves as an effective mechanical alternative for growbag filling.

Laboratory testing was carried out using the potting mixture of ratio 1:1:1 and filled in 20×20×30 cm size growbag. The laboratory testing of the auger type growbag filling unit has indicate that growbag is filled in short period of time with high efficiency up to 77 per cent.

Various maintenance procedures were followed in the beginning to ensure maximum efficiency of the implement during the testing. The major aspects that were checked for maintenance included, check the tightness of belt, proper oiling, cleaning of the clogged particle from the auger. Performance evaluation for the auger type growbag filling unit was then carried out for different variations in five parameters *viz.* standard deviation, coefficient of variation, growbag filling time, capacity of unit, efficiency of unit.

The moisture content, bulk density, particle density, porosity, fineness modulus, pH, angle of repose, electrical conductivity and uniformity of the potting mixture is obtained as 15 per cent, 1.11 $g{\cdot}cm^{-3}$, 1.47 $g{\cdot}cm^{-3}$, 24.49 per cent, 5.45, 6.74, 45.54°, 2.12 $dS{\cdot}m^{-1}$ and 1.29 per cent (maximum deviation) respectively. Capacity of screw conveyor is 414.37 $kg{\cdot}h^{-1}$ at 130 rpm. Total 92 growbags (medium) were filled in one hour. Percentage variation was observed to be 4.47 per cent.

From the laboratory testing and analysis, it was understood that further modifications to the developed unit would ensure the uniform filling of growbags and even discharge from the outlet as well as improve the performance.

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APPENDIX-I

DESIGN CALCULATIONS

1. Design procedure of a screw conveyor

Step 1: Establish the conveying requirement

Requirement: To get an output of 400 $kg \cdot h^{-1}$

Step 2: calculate the capacity of the screw conveyor

Assumed screw diameter, D = 9.5 cm.

Shaft diameter, d = 3.2 cm.

Pitch, P = 2.54 cm.

Theoretical pitch volume of screw conveyor, V_{th} (cm^3) $= \frac{\pi}{4}(D^2 - d^2) \times P$

$= \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54$

$V_{th} = 159.53\ cm^3 \cdot min^{-1}$

$Q_{th} = 2.659 \times 10^{-6}\ m^3 \cdot sec^{-1}$

Theoretical mass capacity of screw conveyor, M° (kg/h) = ($Q_{th} \times \rho \times 3600$)

$= 2.659 \times 10^{-6} \times 1110 \times 3600$

M° = 10.625 $kg \cdot h^{-1}$

Maximum loading ratio, α = 0.30

For inclined screw conveyor design: Define screw conveyor is flat (which is always preferable) or has to be inclined.

Correction factor, $C = 1$

Bulk density of potting mixture, ρ = 1110 $kg \cdot m^{-3}$

Adjust the screw speed so that the capacity of the screw is higher than the requirement.

Capacity,

$$M^o = \frac{\pi}{4}(D^2 - d^2) \times P \times N \times \alpha \times \rho \times C \times 60$$

For different rpms

Below 90 rpm, the conveyance get interrupted

For 90 rpm,

$$M^o = \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54 \times 90 \times 0.30 \times 1110 \times 1 \times 60 \times 10^{-6}$$

$= 286.87\ kg{\cdot}h^{-1}$

For 100 rpm,

$$M^o = \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54 \times 100 \times 0.30 \times 1110 \times 1 \times 60 \times 10^{-6}$$

$= 318.74\ kg{\cdot}h^{-1}$

For 110 rpm,

$$M^o = \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54 \times 110 \times 0.30 \times 1110 \times 1 \times 60 \times 10^{-6}$$

$= 350.62\ kg{\cdot}h^{-1}$

For 120 rpm,

$$M^o = \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54 \times 120 \times 0.30 \times 1110 \times 1 \times 60 \times 10^{-6}$$

$= 382.49\ kg{\cdot}h^{-1}$

For 130 rpm,

$$M^o = \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54 \times 130 \times 0.30 \times 1110 \times 1 \times 60 \times 10^{-6}$$

$= 414.37\ kg{\cdot}h^{-1}$

For 140 rpm,

$$M^o = \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54 \times 140 \times 0.30 \times 1110 \times 1 \times 60 \times 10^{-6}$$

$= 446.37\ kg{\cdot}h^{-1}$

For 150 rpm,

$$M^o = \frac{\pi}{4}(9.5^2 - 3.2^2) \times 2.54 \times 150 \times 0.30 \times 1110 \times 1 \times 60 \times 10^{-6}$$

$= 478.12\ kg{\cdot}h^{-1}$

Step 3: Compare the calculated capacity to the maximum screw speed.

2. Power

$$P = P_H + P_N + P_{St}$$

And

$$P_H = \frac{IML\lambda}{367}$$

Where,

Mass flow rate, I_m = 1.381 $t \cdot h^{-1}$

Conveying length, L = 0.3 m

Progress resistance coefficient, λ = 3

$$P_H = \frac{ImL\lambda}{367} = \frac{1.381 \times 0.3 \times 3}{367} = 3.384 \text{ watts}$$

$$P_N = \frac{DL}{20}$$

Where,

Screw diameter, D = 0.095m

$$P_N = \frac{DL}{20} = \frac{0.095 \times 0.3}{20} = 1.425 \text{ watts}$$

- Power due to inclination, $P_{St} = 0$
- Drive power of loaded screw, $P = P_H + P_N + P_{St}$

= 0.00338 + 0.00142 + 0

= 0.0048 kW

= 0.0064 hp

If the hp < 1, then corrected hp = 2× hp = 2 × 0.0064 =0.0129 hp

Taking factor of safety, FOS = 3

Power required = 3 × 0.0129 = 0.0386 hp = 0.0289 kW ≈ 30 W

3. Design procedure of a shaft

Diameter of driven pulley, d_1 = 15 cm

Diameter of driving pulley, d_2 = 8 cm

Speed of driven pulley, N_1 = 130 rpm

Speed of driving pulley, $N_2 = \frac{N_1 \times d_1}{d_2}$ = 244 rpm

Coefficient of friction between belt and pulley, μ = 0.28

Angle of groove on the pulley, 2β = 40°

Permissible shear stress, $\tau = 50$ MPa

$\sin\alpha = \frac{d_1 - d_2}{2x} = \frac{15-8}{2\times 32.5}$ = 0.107

α = 6.18°

Angle of lap, θ = 180−2α =167.64°

θ =167.64° = $\frac{167.64° \times \pi}{180}$ = 2.926 rad

Mass of the belt per meter length, m = $\frac{1.06}{9.81}$ = 0.108 kg·m^{-1}

Velocity of the belt, v = $\frac{\pi \times d_2 \times N_2}{60} = \frac{\pi \times 0.08 \times 244}{60}$ =1.02 m·s^{-1}

Centrifugal tension, $T_c = m \cdot v^2 = 0.108 \times 1.02^2$ = 0.112 N

$\frac{T_1}{T_2} = e^{\mu\theta \times \text{cosec}\,\beta} = e^{0.28 \times 2.926 \times \text{cosec}\,20°}$ = 10.973

Power, P = $(T_1 - T_2) \times$v

30 = $(T_1 - T_2) \times 1.02$

$T_1 - T_2$ = 29.412

$10.973T_2 - T_2$ = 29.412

T_2 = 2.949 N

T_1 = 32.361 N

Torque transmitted by the driven pulley shaft, $T = \frac{P \times 60}{2\pi N_1} = \frac{30 \times 60}{2\pi \times 130}$ = 2.204 N·m

Since the driven pulley is overhung and the distance of the centre from the nearest bearing is 10 cm, therefore bending moment on the shaft due to the pull on the belt,

$M = (T_1 + T_2 + 2 \cdot T_c) \times$ overhung distance $\times$ number of belt

$M = (32.361 + 2.949 + 0.224) \times 0.1 \times 1 = 3.553$ N·m

Equivalent twisting moment, $T_e = \sqrt{T^2 + M^2} = \sqrt{2.204^2 + 3.553^2} = 4.181$ N·m

For minor shock loads,

Combine shock and fatigue factor applied to M, $K_b = 2$

Combine shock and fatigue factor applied to T, $K_t = 1.5$

Design diameter of coupling shaft, $D^3 = \frac{16}{\pi \times \tau} \times \sqrt{(K_b \cdot M)^2 + (K_t \cdot T)^2}$

$= \frac{16}{\pi \times 50 \times 10^6} \times \sqrt{(2 \times 3.553)^2 + (1.5 \times 2.204)^2}$

$= 9.47$ mm ≈ 10 mm

D = 10 mm

APPENDIX-II

CALCULATION OF BULK DENSITY AND ENERGY CONSUMPTION

1. Moisture content

Initial weight of the sample = 250 g

Final weight of the sample = 217.39 g

Moisture content, % = $\frac{[M1 - M2]}{M2} \times 100$

$= \frac{250 - 217.39}{217.39}$

$=$15 per cent

2. Bulk density

Length of the container = 30 cm

Width of the container = 10 cm

Depth of the container = 9 cm

Volume of the container = 2700 cm^3

Weight of the container = 900 g

Weight of the container with material = 3900 g

Weight of the material in the container = 3900 – 900 = 3000 g

Bulk density $\rho_b = \frac{W_b}{V_b}$

$= \frac{3000}{2700}$ = 1.11 $g \cdot cm^{-3}$

3. Particle density

Weight of the container = 87g

Weight of the dry sample = 250g

Volume of the water filled in the beaker = 400 mL

Volume = 570 mL

Volume of sample = 570 – 400 = 170 mL

Partiucle density, $\rho_s = \frac{W_s}{V_s}$

$= \frac{250}{170} = 1.47$ g·cm^{-3}

4. Porosity

Bulk density = 1.11 g·cm^{-3}

Particle density = 1.47 g·cm^{-3}

Porosity = $[1 - (\frac{\rho_b}{\rho_s})] \times 100$

$= [1 - (\frac{1.11}{1.47})] \times 100$

= 24.49 per cent

5. Fineness modulus

Moisture content (%)	Fineness modulus S:C:FYM = 1:1:1
15	5.42
	5.13
	5.82

The mean value is taken,

Fineness modulus $= \frac{5.42+5.13+5.82}{3}$

= 5.45

6. pH

Moisture content (%)	pH S:C:FYM = 1:1:1
15	6.74
	6.74
	6.74

The mean value is taken,

$$pH = \frac{6.74+6.74+6.74}{3}$$

$$= 6.74$$

7. Angle of repose

Moisture content (%)	Angle of repose, (degree)
	S:C:FYM = 1:1:1
15	45.23
	46.11
	45.79

The mean value is taken,

$$\text{Angle of repose} = \frac{45.23+46.11+45.79}{3}$$

$$= 45.54°$$

8. Electrical conductivity

Moisture content (%)	Electrical Conductivity ($dS{\cdot}m^{-1}$)
	S:C:FYM = 1:1:1
15	2.13
	2.17
	2.05

The mean value is taken,

$$\text{Electrical conductivity} = \frac{2.13+2.17+2.05}{3}$$

$$= 2.12\ dS{\cdot}m^{-1}$$

9. Uniformity

Moisture content (%)	Uniformity of mixture (Deviations from reference bulk density, %)		
	S:C:FYM = 1:1:1		
	Top	Middle	Bottom
15	-1.83	0.41	1.22
	-2.05	-1.23	2.05
	-2.69	-0.83	0.62

The mean value is taken,

$$\text{Deviation from the reference bulk density (top)} = \frac{(-1.83)+(-2.05)+(-2.69)}{3}$$

$$= -2.19\%$$

$$\text{Deviation from the reference bulk density (middle)} = \frac{(0.41)+(-1.23)+(-0.83)}{3}$$

$$= -0.55\%$$

$$\text{Deviation from the reference bulk density (bottom)} = \frac{(1.22)+(2.05)+(0.62)}{3}$$

$$= 1.29\%$$

APPENDIX-III

PERFORMANCE EVALUATION

1. Time taken for filling growbags

Time taken for filling of small growbag $= \frac{60 \times 60}{414.37} \times 2.4$

$= 20.85$ sec

Time taken for filling of medium growbag $= \frac{60 \times 60}{414.37} \times 4.5$

$= 39.09$ sec

Time taken for filling of large growbag $= \frac{60 \times 60}{414.37} \times 6.5$

$= 56.47$ sec

2. Number of bags filled in one hour

Number of small growbags filled in one hour $= \frac{414.37}{2.4} = 172$

Number of medium size growbags filled in one hour $= \frac{414.37}{4.5} = 92$

Number of large size growbags filled in one hour $= \frac{414.37}{6.5} = 63$

3. Efficiency

- Actual capacity = 321.4 kg
- Theoretical capacity = 414.37 kg

Efficiency $= \frac{\text{Actual capacity}}{\text{Theoretical capacity}} \times 100 = \frac{321.4}{414.37} \times 100 = 77\%$

APPENDIX-IV

COST ESTIMATION

1. Fixed cost

Sl. No.	Component	Materials used	Quantity	Unit	Rate (Rs. per unit)	Total cost (Rs.)
1.	Main frame	MS Angle (3 cm width 3 mm thickness)	17.75	kg	57	1011.86
		MS flat	5.97	kg	55	328.24
		GI square pipe	2.02	kg	48	96.86
		M S plate	6.22	kg	75	466.27
2.	Large Hopper	Aluminium sheet (3 mm thickness)	5.20	kg	245	1269.10
3.	Small hopper	GI sheet	2.34	kg	51	119.34
4.	Screw auger flight	Stainless steel (2 mm thickness)	0.79	kg	195	153.27
5.	Screw auger Shaft	MS rod	1.89	kg	35	66.25
6.	Screw auger casing	GI sheet (3 mm)	2.47	kg	51	126.17
7.	Driving pulley	Cast iron (Diameter 8 cm)	01	No.	300	300.00
8.	Driven pulley	Cast iron (Diameter 15 cm)	01	No.	200	200.00
9.	Belt	Rubber	01	No.	250	250.00
10.	Pedal switch	-	01	No.	300	300.00
11.	Plummer block	-	02	Nos.	664	1328.00
12.	Prime mover	-	01	No.	7900	7900.00
13.	Paint (200 mL)	-	02	Nos.	96	192.00
14.	Primer (200 mL)	-	01	No.	52	52.00
15.	Labour charge	-	07	Days	800	5600.00
					Total cost, Rs.	**19,759.32**

Depreciation $= \frac{P-S}{L \times H}$

$= \frac{19759.32 - 1975.932}{5 \times 100}$

$= 35.56$ Rs·h^{-1}

Fixed cost per hour (Rs.) = 35.56

Adding miscellaneous cost, total cost = Rs. 20,352/-

2. Operational cost

Energy consumed (kWh) = Power × Time

= 0.0289 × 1

= 0.0289 kWh

Electricity charge = 0.0289 × 8

= Rs. 0.2312/-

Labour charge per day = 1 (No. of person) × 800

= Rs. 800/-

DESIGN AND DEVELOPMENT OF AN AUGER TYPE GROWBAG FILLING SYSTEM

by

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ABSTRACT

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DEPARTMENT OF FARM MACHINERY AND POWER ENGINEERING

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ABSTRACT

The research paper depicts the design and development of auger type growbag filling unit for easy filling of growbags. India is an agriculture-based country. Majority of the population primarily depends on agriculture. Our farmers follow the same traditional way for ages. There is a need of mechanization in the agriculture sector. This results in higher productivity and precision in agriculture. Growbag cultivation is getting popular in our state due to urbanisation. It necessitated easy method of filling growbags as per the favourable agronomic conditions for crop growth. A growbag filling unit was hence developed and tested for filling growbags of different size. The unit consists of an electric motor (1 hp), a feeding chute, a screw auger with small hopper, driving and driven pulley, V-belt and main frame. Potting mixture is discharged through the feeding chute and conveyed through the screw auger by the rotational and horizontal motion of the auger blade.The developed prototype was tested in laboratory, in order to optimize the operational parameters *viz.* machine and material parameters in the ratio of S:C:FYM as 1:1:1. Dried soil, coir pith and FYM mixed and filled in the growbags. The properties such as bulk density (1.11 $g \cdot cm^{-3}$), particle density(1.47 $g \cdot cm^{-3}$), porosity (24.49 per cent), fineness modulus (5.45), pH (6.74), angle of repose (45.54°), electrical conductivity (2.12 $dS \cdot m^{-1}$) and uniformity (1.29 per cent- maximum deviation) of the potting mixture were observed at the ratio1:1:1 (S:C:FYM) at the moisture content of 15 per cent. Performance parameters such as time of operation (39 seconds, medium size bag), capacity of the unit (414.37 $kg \cdot h^{-1}$), number of bags filled (92, medium size bags), average variation (4.47%) and energy consumption (0.0289 kWh) were obtained with an overall efficiency of 77 per cent.

Total cost of unit including miscellaneous costs is Rs. 20,352/- and the operational cost was found to be around Rs. 140/- per hour.