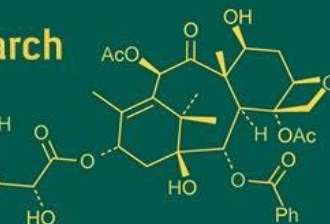
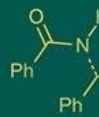
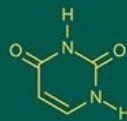
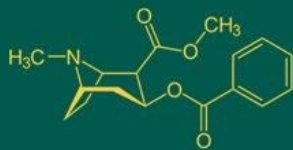


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Development and performance evaluation of semi-automatic nursery grow bag filling machine

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Abstract

Preparation of media is a critical operation in horticultural nurseries. Manual media filling in polybags is labour-intensive, time-consuming, and inefficient. To address these challenges, a semi-automatic nursery grow bag filling machine was designed and developed for small-scale horticultural nurseries. The machine comprises a hopper, rotating magazine, cups, outlet pipe, electric motor, and safety guard, powered by a 1 HP single-phase motor. Media such as cocopeat, vermicompost, and their mixture are fed through the hopper, with filled bags collected at the outlet.

Performance evaluation was conducted using Design Expert 10 software to study the effect of operational parameters, including motor speed (6, 8, 10 rpm) and moisture content (10–50%), on output parameters. Results showed that 6 rpm provided the highest productivity and consistent bag weight. Vermicompost, with 10–20% moisture content, delivered optimal performance, while higher speeds and moisture levels reduced efficiency. Vermicompost consistently outperformed cocopeat and its mixture with cocopeat, which showed sensitivity to increased speed and moisture.

The findings align with prior research on media characteristics and their influence on horticultural practices. Chemical and physical properties of cocopeat mixtures significantly impact plant growth, supporting observations on the moisture sensitivity of cocopeat (Awang *et al.* (2009)). Mason and Evans (2018) highlighted challenges in manual bag filling and the importance of mechanization in improving nursery operations, emphasizing the practical benefits of semi-automation. The role of optimized media in container-based horticulture, underscoring vermicompost's superior performance (Colombo *et al.* (2016)).

For best results, operating the machine at 6 rpm with 10–20% moisture content using pure vermicompost is recommended. High moisture levels (30% and above), particularly for cocopeat, should be avoided to ensure efficient performance. These recommendations are consistent with broader studies on mechanized nursery practices and potting media optimization (Selvan *et al.*, 2015; Sujitha and Shanmugasundaram, 2017).

Keywords: Media, cocopeat, vermicompost, growbag, bulk density of media, operating cost

Introduction

The grow bag filling process is a critical operation in horticultural nurseries that directly affects plant growth and operational efficiency. Traditionally, this process is carried out manually, requiring significant labour and time. Workers mix media like cocopeat, vermicompost, or a combination of both using spades and then manually fill the media into polybags. This manual method is labour-intensive, time-consuming, and often results in inconsistencies in media weight and quality.

Ingredients like soil, cocopeat, vermicompost, and sand are sourced and prepared for mixing. Workers use shovels, spades, or hands to mix these ingredients to achieve a uniform media composition. Ratios of materials vary depending on the type of crop being cultivated and nursery requirements (e.g., higher cocopeat for water retention in vegetable nurseries) (Awang *et al.*, 2009) [1].

Laborers, often seated on the ground or on low stools, use containers, cups, or their hands to scoop media and fill it into polybags or grow bags. Bags are manually tamped down to ensure proper compaction and avoid air pockets. Once filled, the grow bags are manually moved and placed in designated nursery areas for plantation. Filled bags are usually stacked

or arranged in rows to optimize space. The process is repeated for hundreds or thousands of grow bags daily, depending on the workforce and nursery scale (Mason & Evans, 2018) ^[5].

Workers rely solely on manual effort for all tasks, including media preparation, mixing, and filling. Output is limited to about 150–200 bags/day per person due to the labour-intensive nature of the work. This method is cost-effective for operations with low production demands and is widely used for raising vegetables, ornamental plants, and fruit saplings. However, the reliance on manual labour presents several limitations. During peak nursery seasons, a significant number of workers are required, and labour shortages can hinder timely completion of operations (Thompson & Brown, 2019) ^[14].

Additionally, filling each bag manually is slow compared to semi-automatic or automated systems, reducing overall productivity. Bag weights and filling levels vary due to human error, leading to inconsistent growth conditions for plants. Workers often perform tasks in stooped or seated positions, leading to fatigue, strain, and long-term health issues. Manual handling of media can result in spillage and wastage, increasing material costs over time (Baker & Clark, 2018; Selvan *et al.*, 2015) ^[2, 12].

Materials and Methods

Design Concept

Designing a semi-automatic growbag-filling machine for nursery use requires a focus on functionality, efficiency, and user convenience. The large trapezoidal structure at the top acts as a hopper, which stores the growing media such as cocopeat, vermicompost, or a mixture. Its wide opening allows for easy loading of the media. The hopper's design ensures a smooth flow of material downward due to gravity. The blue vertical shaft connected below the hopper is driving a rotating magazine. The rotating system ensures that media is dispensed into growbags sequentially and uniformly. A single-phase electric motor (visible at the top left) provides the required power to drive the system. The

motor is connected to the filling mechanism through sprockets and a chain transmission system. This setup helps regulate the rotational speed and torque as per the operational requirement. The pipe at the bottom right serves as the outlet for dispensing the media into the growbags. The controlled flow ensures consistent filling with minimal spillage.

The machine is mounted on a sturdy metal frame painted black, providing structural stability. The frame is equipped with wheels, allowing for easy mobility and relocation within the nursery. A safety guard is placed near the sprocket and chain transmission system to prevent accidents during operation, ensuring operator safety. The overall design of the machine is compact, making it suitable for small-scale nurseries. It minimizes space requirements while maximizing operational efficiency.

The media is loaded into the hopper and flows downward due to gravity. The motor-driven rotating magazine facilitates sequential filling of growbags through the outlet pipe. The machine's design focuses on reducing manual labour, improving precision in bag filling, and enhancing overall efficiency. This design concept reflects a practical and ergonomic approach to addressing the challenges of manual nursery bag filling.

Different Parts of Developed Working Machine

Table 1: Different Parts of The Developed Working Machine

Sr. No	Part name
1	Hopper
2	Cup
3	UCF bearings
4	Flange ball bearings
5	Motor
6	Supporting frame
7	Shafts
8	Chains and sprockets
9	Plates

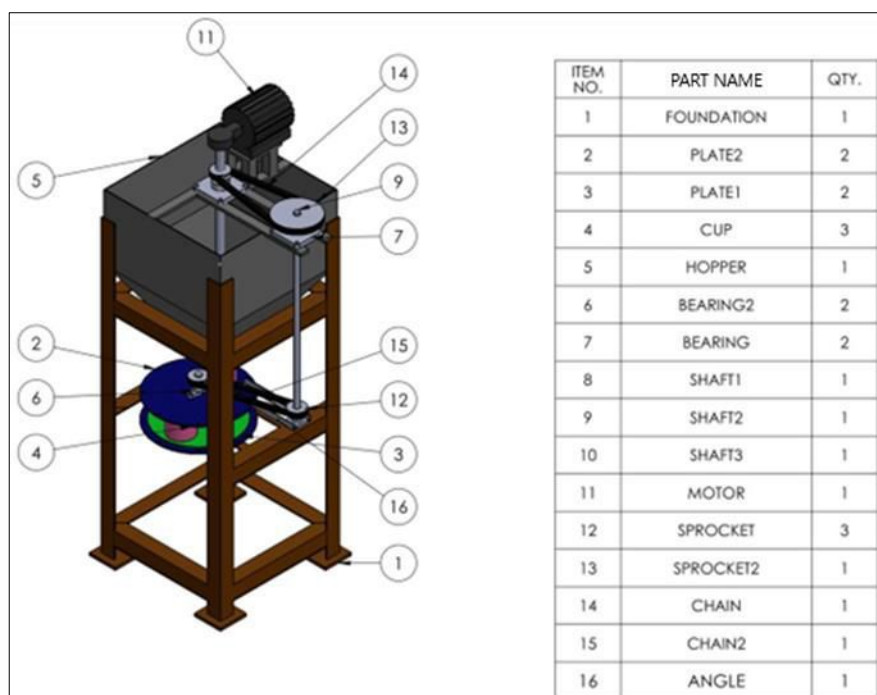


Fig 1: Assembly of Semi-automatic nursery growbag filling machine

1. Hopper

The hopper is the unit through which soil will be inserted in the polythene bags. At the end of hopper there is seed control plate which is also made up of MS Sheet will open or close the hopper due to pedal operated lever.

2. UCF bearings

UCF typically stands for "Universally Interchangeable Flanged Bearing". UCF Bearings are housed bearing units that consist of a bearing and housing made from cast iron. They typically have a spherical outer diameter to accommodate misalignment. These bearings are widely used in industrial machinery, conveyor systems, agricultural equipment, and other applications where there's a need for a mounted bearing that can handle radial loads and moderate axial loads.

3. Supporting Frame

A supporting frame often referred to simply as a frame, serves as a structural skeleton that provides stability, support, and rigidity to various types of equipment, structures, or systems. Frames are designed to bear and distribute loads effectively, ensuring stability and preventing deformation or failure. They provide a framework for mounting components or modules securely, maintaining alignment and facilitating efficient operation. Frames enhance the overall rigidity of the system or equipment, minimizing vibrations and improving operational precision. Mild Steel are commonly used for their strength, durability, and resistance to corrosion. They are suitable for heavy-duty applications requiring robust support. Frames must be designed to support anticipated loads, considering static and dynamic forces, impacts, and vibrations. Frames will facilitate easy assembly and integration with other components or systems, supporting efficient manufacturing and maintenance processes.

4. Flange Ball Bearings

Flange ball bearings are a specific type of ball bearing that incorporates a flange, which is an external rim or collar, around the outer ring of the bearing. Flange ball bearings have an extended outer ring with a flange that acts as a built-in willer to accurately position the bearing in the housing. This design helps in easy mounting and alignment of the bearing. They are commonly used in applications where axial positioning is critical or where space constraints prevent the use of separate housing for the bearing. Examples include machinery with limited mounting space, such as in conveyor systems, automotive applications, and some types of agricultural equipment. Flange ball bearings are available in various sizes and configurations to accommodate different load capacities, speeds, and environmental conditions.

5. Motor

A 100 RPM worm gear motor refers to a specific type of electric motor combined with a worm gearbox that outputs rotational speed at approximately 100 revolutions per minute (RPM). Standard AC motors are used generally as a power source for automated equipment, because these motors can be operated easily by connecting the motor

directly to an AC power supply. Typically, these motors are low-speed alternating current (AC) motors paired with a worm gearbox. The gearbox consists of a worm gear and a mating gear, which reduces the output speed while increasing torque. Worm gear motors are known for their high torque output relative to their size and speed.

6. Shafts

A shaft is a cylindrical rod or bar, usually made of metal, that rotates to transmit power or motion. It typically has one or more keyways, splines, threads, or other features for connecting and transmitting torque to other components. Shafts transfer rotational motion from a driving source to driven components (e.g., gears, pulleys, wheels). They support rotating elements such as gears, bearings, and pulleys, maintaining alignment and reducing vibration. Shafts that change diameter at specific points, allowing for varied torque transmission or bearing support.

7. Chains and sprockets

Chains are flexible assemblies of interconnected links that engage with teeth on sprockets to transmit rotary motion and torque. Sprockets are toothed wheels that mesh with the links of a chain, transferring rotational motion. They transfer power from one shaft to another, often over distances, while accommodating misalignment and allowing for flexibility. Most common type, with rollers between inner and outer links that engage with sprocket teeth. Chains are typically made from steel or stainless steel for strength and durability, with options for corrosion resistance. Made from cast iron, selected based on application.

8. Plates

MS circular plates are flat, round metal discs made from mild steel. Mild Steel (MS) circular plates are widely used in various industries for their versatility, strength, and ease of fabrication. Mild steel is relatively inexpensive compared to other steel alloys, making it a cost-effective choice for many applications.

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.

1. Selection of media

In the Kolhapur district, the media is mostly used for growing horticultural seedlings, plants and crops. The cocopeat and vermicompost is used as medium to support seedling or plants to nurture it. As per crop requirement, different crops require different media for its growth. This selected media was used for performance evaluation.

2. Physical properties of media

The physical properties of media viz. bulk density, moisture content, angle of repose, total porosity, particle density and particle size distribution were determined using standard procedures

Table 2: Physical properties of media

Sr. No.	Property	Medium	Readings
1	Bulk Density	Vermicompost	0.7 g/cm ³
			0.8 g/cm ³
			0.9 g/cm ³
		Cocopeat	0.45 g/cm ³
			0.35 g/cm ³
			0.30 g/cm ³
		Vermicompost + Cocopeat	0.65 g/cm ³
			0.72 g/cm ³
2	Moisture Content	Vermicompost	10 %
			20 %
			30 %
		Cocopeat	30 %
			40 %
			50 %
		Vermicompost + Cocopeat	20 %
			30 %
3	Angle of repose	Vermicompost	39°
			32°
			27°
		Cocopeat	29.8°
			25.6°
			23.8°
		Vermicompost + Cocopeat	31.3°
			30.6°
			28.9°

3. Weight of bags filled

Small 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.

4. 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.

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.

5. Energy consumption.

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

6. 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 hopper. Efficiency was calculated at different moisture contents of the material

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.

Results and Discussion**1. Performance evaluation of semi-automatic nursery bag filling machine.****Capacity of machine**

The capacity of nursery bag filling machine was determined by using the standard procedure. The known quantity of media was fed to the hopper at constant rate for fifteen minutes. The quantity of media at outlet was measured after fifteen minutes to determine the capacity of machine. Capacity of machine varied from 100 kg/h at feed rate 125 kg/h, Gear speed 6 rpm 8 rpm, 10 rpm respectively and magazine speed 6 rpm, 8 rpm, 10 rpm. with the mean capacity of 480 bags/h during operation of nursery bag filling machine at different operating conditions. As the gear speed increases from 6rpm to 10rpm capacity of machine increases and similar trend is observed for magazine speed from 6 to 10 rpm. It might be due to gear speed increases, large amounts of media passed through magazine tubes. As magazine speed increases, capacity of machine also increases. Hence capacity of machine increases at higher speed.

Table 3: Observations taken from experimental run on semi-automatic nursery bag filling machine

Sr. No.	Gear Speed (rpm)	Material	Moisture Content (%)	No. of Bags Filled	Average Weight filled In Bags (grams)
1	6	Vermicompost	10	350	373
2	8	Vermicompost	20	460	361
3	10	Vermicompost	30	575	355
4	6	cocopeat	30	341	351
5	8	cocopeat	40	458	339
6	10	cocopeat	50	567	333
7	6	Vermicompost + cocopeat	20	345	357
8	8	Vermicompost + cocopeat	30	465	348
9	10	Vermicompost + cocopeat	40	575	339

2. ANOVA for study of effect of vermicompost media filling at outlet with different gear speed, magazine speed on capacity of machine.

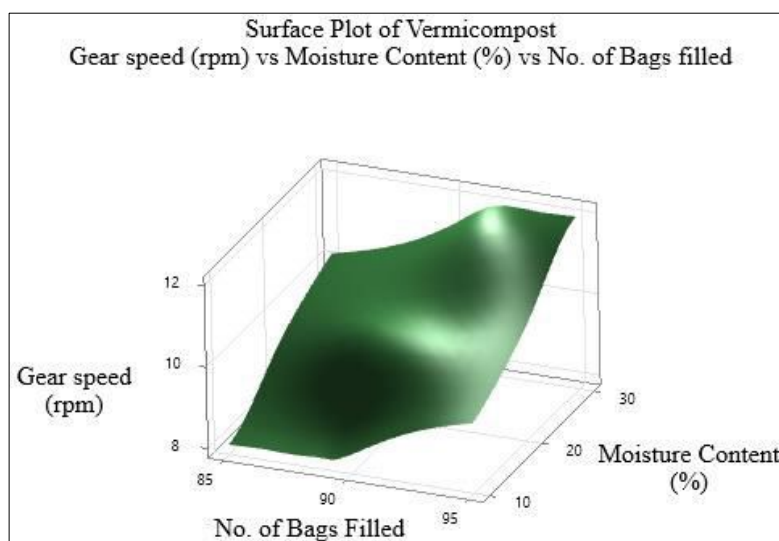
The ANOVA given in Table indicates that, the high value of model F (0.17729) and (3.04013) suggesting quadratic model could be successfully used to fit experimental data ($p < 0.001$). As per F-values indicated in Table, the term of feed rate, gear speed, magazine speed had significant effect

on the capacity of machine at 1 per cent level of significance. Similarly, the interaction terms of feed rate $\times$ Gear speed had significant effect on capacity of machine. No significant effect was found in case of all the interactions of the parameter except interaction of feed rate and gear speed. The results suggest significant difference between moisture content levels and speed of gears has impact on weight of material filled and number of bags filled.

Table 4: ANOVA for study of the effect of moisture content and gear speed on capacity of machine for vermicompost media.

Summary			Count	Sum	Average	Variance
6	vermicompost	10	2	432	216	29282
6	vermicompost	20	2	426	213	29768
6	vermicompost	30	2	436	218	31250
8	vermicompost	10	2	430	215	28800
8	vermicompost	20	2	417	208.5	28084.5
8	vermicompost	30	2	425	212.5	28560.5
10	vermicompost	10	2	435	217.5	30504.5
10	vermicompost	20	2	402	201	25088
10	vermicompost	30	2	412	206	26450
No. of Bags filled			9	831	92.33333	4.75
Average soil filled (wt)			9	2984	331.5556	93.77778
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Rows	523.4444	8	65.43056	1.97692	0.17729*	3.438101
Columns	257522.7	1	257522.7	7780.796	3.04013*	5.317655
Error	264.7778	8	33.09722			
Total	258310.9222	17				

At 1 % level of significance.

**Fig 2:** Effect of gear speed and moisture content on capacity of machine for vermicompost media

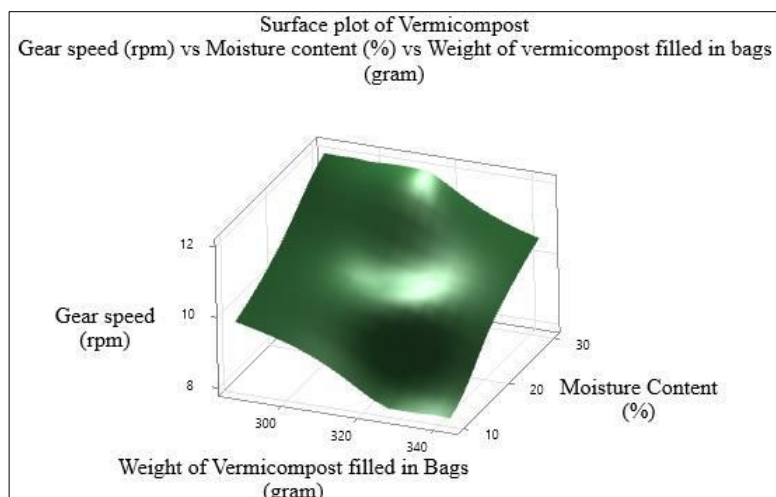


Fig 3: Effect of gear speed and moisture content weight of vermicompost filled by machine for vermicompost media.

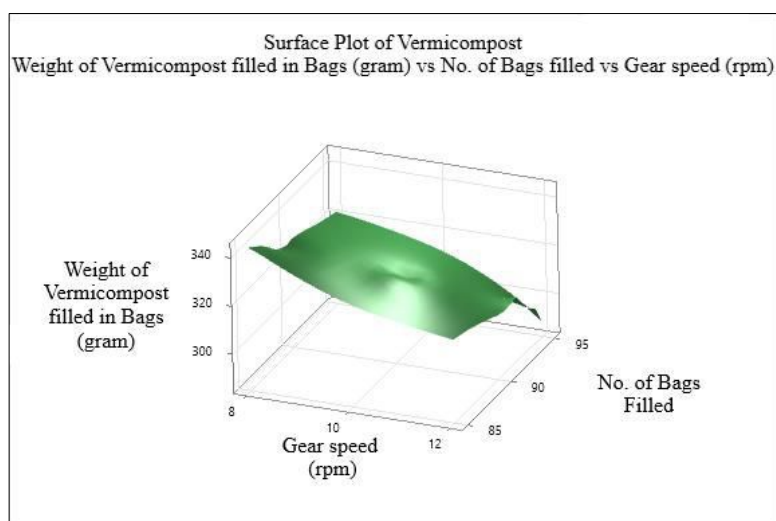


Fig 4: Effect of weight of vermicompost filled and gear speed on capacity of machine for vermicompost media.

ANOVA for study of effect of cocopeat media filling at outlet with different gear speed, magazine speed on capacity of machine.

The ANOVA given in Table indicates that, the high value of model F (1.97692) and (7780.796) suggesting quadratic model could be successfully used to fit experimental data ($p < 0.001$). As per F-values indicated in Table, the term of feed rate, gear speed, magazine speed had significant effect

on the capacity of machine at 1 per cent level of significance. Similarly, the interaction terms of feed rate $\times$ Gear speed had significant effect on capacity of machine. No significant effect was found in case of all the interactions of the parameter except interaction of feed rate and gear speed. The results suggest significant difference between moisture content levels and speed of gears has impact on weight of material filled and number of bags filled.

Table 5: ANOVA for study of the effect of moisture content and gear speed on capacity of machine for cocopeat media.

Summary			Count	Sum	Average	Variance
6	cocopeat	30	2	432	216	29282
6	cocopeat	40	2	426	213	29768
6	cocopeat	50	2	436	218	31250
8	cocopeat	30	2	430	215	28800
8	cocopeat	40	2	417	208.5	28084.5
8	cocopeat	50	2	425	212.5	28560.5
10	cocopeat	30	2	435	217.5	30504.5
10	cocopeat	40	2	402	201	25088
10	cocopeat	50	2	412	206	26450
No. of bags filled			9	831	92.33333	4.75
Average cocopeat filled (wt.)			9	2984	331.5556	93.77778
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Rows	523.4444	8	65.43056	1.97692	0.17729	3.438101
Columns	257522.7	1	257522.7	7780.796	3.0413	5.317655
Error	264.7778	8	33.09722			
Total	258310.9	17				

At 1 % level of significance.

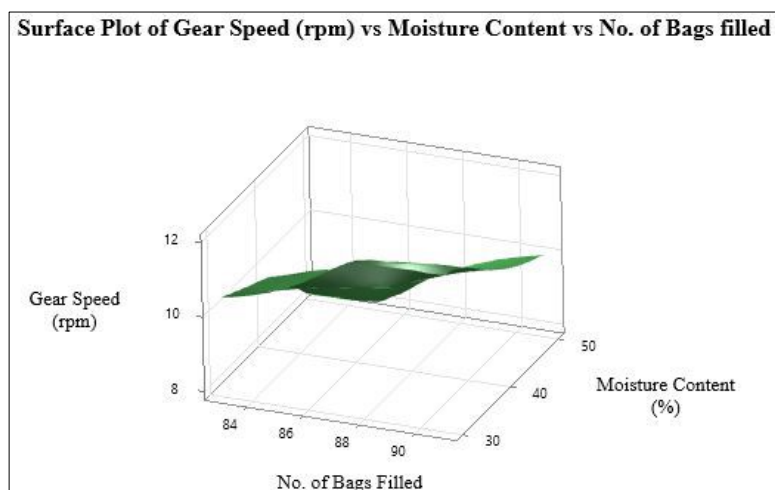


Fig 5: Effect of gear speed and moisture content on capacity of machine for cocopeat media.

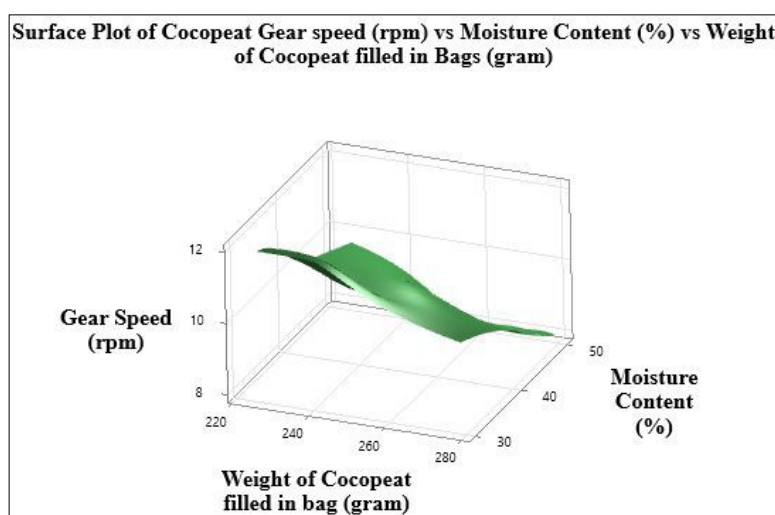


Fig 6: Effect of gear speed and moisture content on weight of cocopeat filled in machine for cocopeat media.

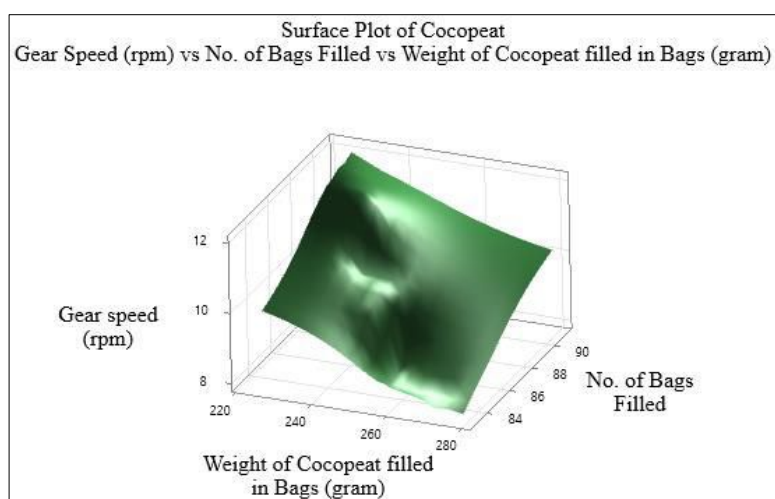


Fig 7: Effect of gear speed and moisture content on capacity of machine for cocopeat media.

ANOVA for study of effect of mixture of vermicompost and cocopeat media filling at outlet with different gear speed, magazine speed on capacity of machine.

The ANOVA given in Table indicates that, the high value of model F (1.97692) and (7780.796) suggesting quadratic model could be successfully used to fit experimental data

($p < 0.001$). As per F-values indicated in Table, the term of gear speed, magazine speed had significant effect on the capacity of machine at 1 per cent level of significance. Similarly, the interaction terms of feed rate $\times$ Gear speed had significant effect on capacity of machine. No significant effect was found in case of all the interactions of the

parameter except interaction of feed rate and gear speed. The results suggest significant difference between moisture

content levels and speed of gears has impact on weight of material filled and number of bags filled.

Table 6: ANOVA for study of the effect of moisture content and gear speed on capacity of machine for mixture of vermicompost and cocopeat media.

Summary			Count	Sum	Average	Variance
6	Vermicompost + cocopeat	20	2	432	216	29282
6	Vermicompost + cocopeat	30	2	426	213	29768
6	Vermicompost + cocopeat	40	2	436	218	31250
8	Vermicompost + cocopeat	20	2	430	215	28800
8	Vermicompost + cocopeat	30	2	417	208.5	28084.5
8	Vermicompost + cocopeat	40	2	425	212.5	28560.5
10	Vermicompost + cocopeat	20	2	435	217.5	30504.5
10	Vermicompost + cocopeat	30	2	402	201	25088
10	Vermicompost + cocopeat	40	2	412	206	26450
No. of bags filled			9	831	92.33333	4.75
Average mixture filled (wt)			9	2984	331.5556	93.77778
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Rows	523.4444	8	65.43056	1.97692	0.17729*	3.438101
Columns	257522.7	1	257522.7	7780.796	3.04013*	5.317655
Error	264.7778	8	33.09722			
Total	258310.9	17				

At 1 % level of significance.

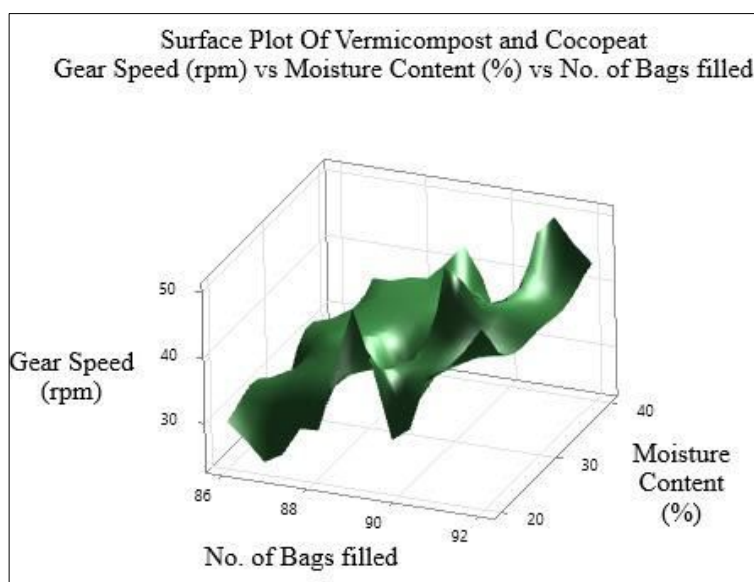


Fig 8: Effect of gear speed and moisture content on capacity of machine for mixture of vermicompost and cocopeat media mixture.

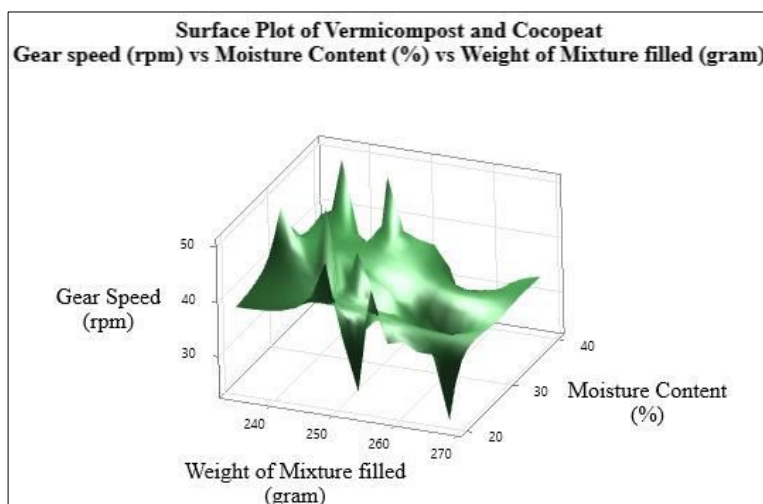


Fig 9: Effect of gear speed and moisture content on weight of mixture filled in machine for mixture of vermicompost and cocopeat media

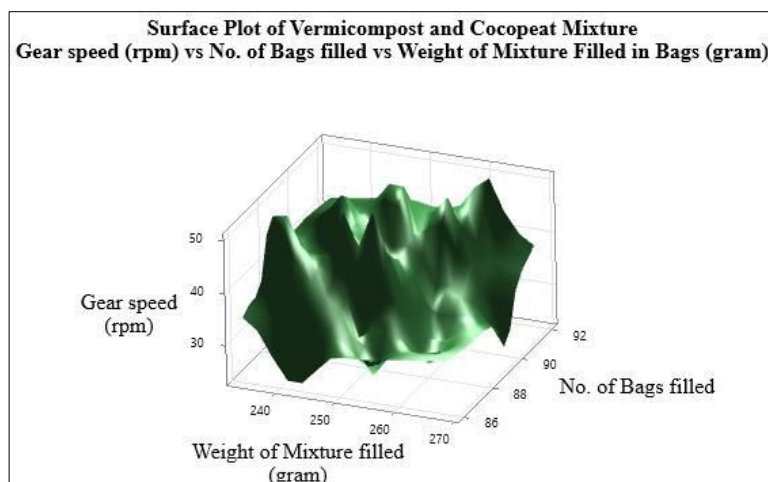


Fig 10: Effect of gear speed and capacity of machine on weight of mixture filled in machine for mixture of vermicompost and cocopeat media.

Cost economics of semi-automatic nursery bag filling machine

The cost economics of the semi-automatic nursery bag filling machine highlights its efficiency and cost-effectiveness, making it a highly suitable investment for nursery operations. The initial fabrication cost of the machine is ₹30,610. The operational costs primarily include electricity charges, which are calculated based on the power of the motor and usage. A motor power of 1 HP (0.746 kW) operating for 8 hours per day at an electricity rate of ₹7 per kWh, the daily electricity cost amounts to ₹41.8. Over 25 working days in a month, this totals ₹1,045 for electricity expenses.

The machine offers substantial savings in labour costs compared to the manual filling method. In the manual process, one labour can fill approximately 150 bags per hour, requiring labour to achieve a daily output of 1,200 bags per day. At a labour cost of ₹300 per person per day, the total labour cost is ₹600. In contrast, the semi-automatic machine achieves a daily output of 4,000 bags with just one operator, costing ₹300 per day. This results in a daily labour cost savings of ₹1500, which translates to ₹37500 per month for 25 working days.

Maintenance costs are also minimal, with an annual maintenance expense estimated at 5% of the fabrication cost, equating to ₹1,530 per year or ₹128 per month. The machine further reduces material wastage, which is another significant source of savings. While manual filling methods result in 5% wastage of daily material (1,000 kg at ₹10/kg), the machine reduces wastage to 1%. This 4% reduction in wastage saves ₹400 per day, or ₹10,000 per month.

The monthly operational costs, including electricity and maintenance, amount to ₹1,173, while the combined monthly savings from reduced labour dependency and material wastage total ₹40,000. This results in net monthly savings of ₹25,337. With an initial investment of ₹30,610, the payback period for the machine is approximately 8 months, making it an exceptionally cost-effective solution. The machine not only improves productivity but also reduces labour dependency and wastage, ensuring a sustainable and profitable operation in the long term.

Summary and Conclusion

Based on result of developed Semi-automatic Nursery growbag filling machine for horticultural crop nursery,

conclusion is drawn on the basis of the research work carried out on "Development and Performance evaluation of Semi-automatic Nursery growbag filling machine" are as follows,

- Optimal Gear Speed:** 6 rpm is the most effective speed, producing the highest number of bags and soil weights. Higher speeds (8 and 10 rpm) result in reduced output.
- Optimal Moisture Content:** Moisture levels between 10-20% provide the best performance. Higher moisture levels (30-50%) significantly reduce the number of bags filled and the soil weight.
- Best Material:** Vermicompost consistently outperforms cocopeat and the vermicompost + cocopeat mixture. It is ideal for achieving maximum productivity.
- Operational Parameters:** For best performance, operate the machine at 6 rpm with 10-20% moisture content using pure vermicompost.
- The media obtained from machine is uniformly filled in each bag which is required for better establishment of nursery sapling.
- The thoroughly mixed media is obtained from developed Semi-automatic nursery growbag filling machine.
- As the moisture content in the media increases by 10%, the amount the media filled in bag is decreased by 5%.
- The semi-automatic nursery growbag filling machine works satisfactorily for preparation and metering the media for horticulture crop nursery.

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