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Automated Floral Foam Cutting Machine for Industry

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Abstract - *The floriculture industry has been growing up in the past thirty years and today Sri Lanka is one of the largest floriculture producing countries in the world. With earnings of around US$ 16 million worth of foreign exchange annually, the floriculture industry has a tremendous potential for generating employment for rural populations. The floral foam is an excellent solid rooting media that use to plant rooted cuttings for export market. Standard size blocks of floral foams are imported and then cut into cubes of four distinct sizes to accommodate different plants. Currently the cutting is being done manually by skilled workers. Even the leading exporters have found it difficult to maintain the quality of floral foams cubes being cut by existing manual cutting method. Requiring skilled labour, generating unproductive time, wastage of material due to irregular cutting, breakages and dust formation are the drawbacks of this manual method. Therefore, this study is focused on designing and developing an automated floral foam cutting machine and validating the same for improved efficiency and product accuracy.*

An automated floral foam cutting machine was designed and developed. It is powered by grid electricity, where all pneumatic and mechanical operations are handled by a micro-controller to a pre-programmed sequence. Specially designed cutters enable size floral foam blocks in both horizontal and vertical directions to specific dimensions with minimum deformation. Cutting time, productivity, product accuracy and wastage were compared with existing manual method. The cost of manufacturing was calculated, and payback period of the capital cost was analyzed.

The results revealed that the automated floral foam cutting machine has improved the productivity by 71%-81%. The geometrical variance is only 0.67. With the new machine dust formation drops by 69%, which is not only significant, but reduce environmental pollution compared to manual method. The machine saves the labour cost by 80%, and the capital cost can be recovered within 8 months.

Key Words: *Floral foam, Cutting machine, Automation, Micro controller, Pneumatics.*

Nomenclature

L - Length in *mm*
W - Width in *mm*
H - Height in *mm*

Subscripts

P - Plants
SD - Standard deviation
CV - Coefficient of variance
AFFCM - Automated floral foam cutting machine
FF - Floral foam

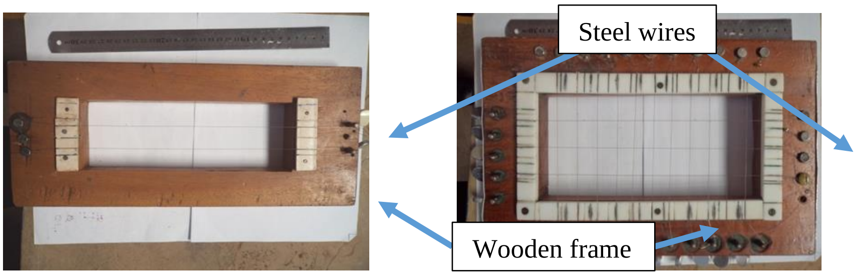
1 INTRODUCTION

The floriculture industry in Sri Lanka has been growing in the past thirty years and since 1980s it has been evolving as an export-oriented industry which provided direct employment to many people from semi-urban to rural areas (De Silva, 2014). Today, Sri Lanka is recognized as one with largest floriculture production centres in the world. Europe is the main market for Sri Lankan floriculture products having 60% of exports, while Japan, Middle East, USA and South Korea make up the other key markets (EDB, 2019). In 2017, Sri Lanka was able to earn US$ 16 million worth of foreign exchange by exporting floriculture to Netherlands, Japan, Saudi Arabia, and UAE (EDB, 2019).

The vast botanical diversity and a wide range of floricultural species (Floriculture sector in Sri Lanka, e-brochure) have made Sri Lanka a favourable location to excel different floriculture markets in the world (Dhanasekara, 1998). Export Development Board (EDB) is the apex state body dealing with export of floriculture products, while the Department of National Botanical Gardens (DNBG) is providing technical expertise to the floriculture industry (Rathnayake and Rathnayake, 2019). Currently around 55 local floriculture exporters are exploring the possibility of expanding their business into emerging markets in Swaziland, Uruguay, and Iraq (Rathnayake and Rathnayake, 2019). Besides resulting in higher income generation, the floriculture sector has also shown tremendous potential for generating employment opportunities for rural populations, particularly for women (Daily News, 2017). In fact, according to the National Planning Framework (2010) Sri Lanka is planning to establish 1500 horticultural villages and 30,000 employment opportunities particularly for sub-urban and rural areas. De Silva (2014) in his article on Daily FT pointed out that Sri Lanka could be the regional leader in horticulture industry soon.

Floriculture planting media 'floral foam (FF)' is imported. Among many other materials FF has been widely used as the rooting materials for stem cuttings as they weigh less, retain water, are packable and can be produced to export standards (EDB, 2019). FF blocks with standard dimension (L230xW110xH80 *mm*) are imported and cut to the required sizes. Four distinct sizes of FF cubes required to accommodate different types of plants. Even though automated cutting machines are available (alibaba.com, D&T Industry Co. Ltd), they are expensive and not affordable by any of the local industries. Depending on the capacity, features and the level of automation the prices of machines available for online purchasing are in the range of US$ 3,000 to 15,000 (Hebei Huiya Floral Foam Special Equipment Co., Ltd., Everen Industry Co. Ltd.).

Mike Flora International (PVT) Ltd is one of the pioneering floriculture-based product exporters in Sri Lanka which exports around 17 million plants of 64 varieties annually to 20 countries around the world. It has a work force of around 300 people (Personnel communication, Mr. WMHD Weerakoon, Supervisor, Nursery Management, Mike Flora Pvt Ltd). They still use labour intensive methods to cut the FF block into cubes in four different sizes. This manual cutting is being done by using cutters made from 0.4 *mm* gauged steel wires fixed to a wooden frame (Fig.1). Since the FF cubes (Fig.2) are different in length, width and height, different sets of cutters with accurately spaced steel wires are required. The cutting should also be performed in two steps as the FF block need to be cut both horizontally and vertically. The manual cutting process which needs skilled labour is not only unproductive but also generates wastages due to odd shaped or deformed or unevenly sized cubes. The dust formation in the cutting process cause health hazards among workers. Further, the steel wires tend to erode and break frequently resulting high downtime. Having seen the mentioned deficits, an automated floral foam cutting machine was designed and developed. The machine could be used by the others in this industry, which contributes to the GDP in Sri Lanka.



a. Vertical cutter b. Horizontal cutter

Fig.1. Horizontal and vertical cutters.

2 METHODOLOGY

This study was conducted at the premises of Mike Flora International (PVT) Ltd, located at Kalagedihena in the Gampaha district. Seeing deficiencies in the existing cutting process, an automated floral form cutting machine was developed to minimize the handling while cutting the floral foam, with more time efficiency, enhanced accuracy, and less wastage. The designing of machine was done considering the following aspects.

- System of operation.
- Structural integrity.
- Strength and durability of cutters.
- Time efficiency in handling and cutting.
- Accuracy in terms of shape and size.
- Wastage in cutting.
- Health hazards to workers.
- Capability of cutting different sizes of blocks (Fig.2) as per the requirement.

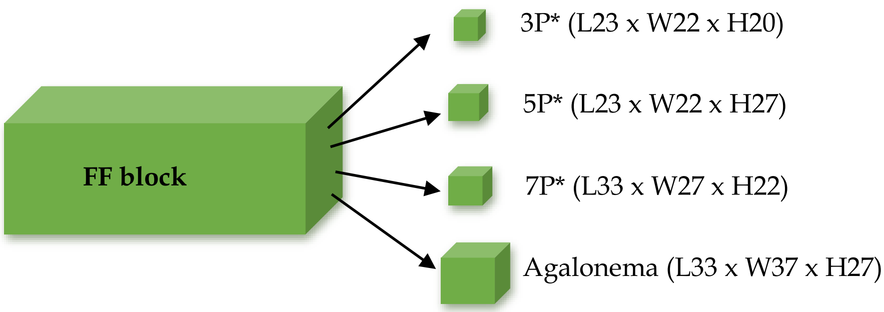


Fig.2. Different sizes (mm) of FF cubes required by the industry for plant types (P)

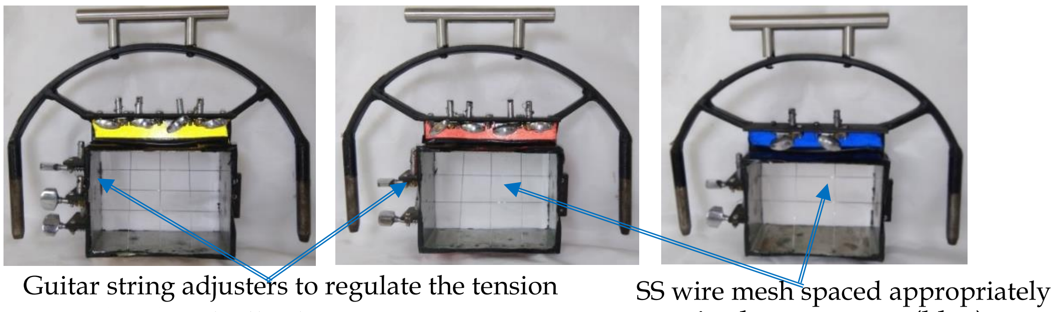
The aim is to develop the machine with low cost while incorporating necessary mechanical and electronic devices for automation. The four different sizes of FF cubes can be produced by just changing the cutters. The performance of the machine was compared with the existing manual process by considering the relevant aspects, using statistical techniques.

3 RESULTS AND DISCUSSION

3.1. Development of the Automated Floral Form Cutting Machine (AFFCM)

The AFFCM was designed and developed with the following main features.

Horizontal Cutters and Cutting Angles: Three different cutters, shown in Fig.3-a, b, c, (yellow, red, and blue colours) are made to accommodate different sizes of FF cubes as mentioned. Cutters were designed to attach and remove easily to the actuator mechanism. Fig.7 shows a cutter fixed to the machine.



a. 3P cutter (yellow) **b. 5P/7P cutter (red)** **c. Agalonema cutter (blue)**

Fig.3. Three different types of horizontal cutters

The FF block is pushed through the cutting wires (of the horizontal cutter) to cut horizontally. Inclined angle of the wires β (Fig.4) is optimized to have a perfect cut with minimum deformation. The cutting force is also varying with β and the Table 1 gives the results of the trials. The best angle with minimum cutting force is 45°. However, considering many factors 55° angle is selected. The cutting quality is excellent at 55° and the selected piston can exert beyond 40 N force.

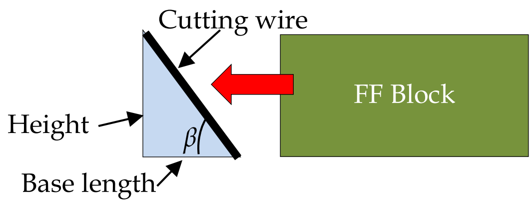
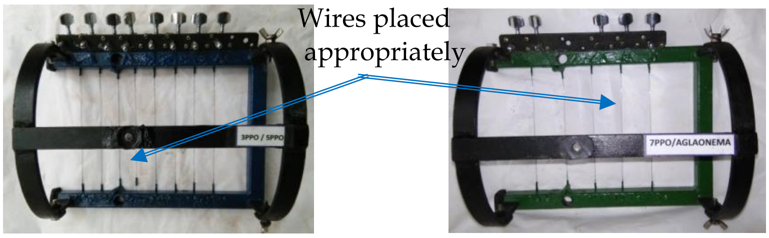


Fig.4. Horizontal cutting with cutting angle β

Table 1 Experimental results on horizontal cutting angle and force

Angle	Base length (*mm*)	Height (*mm*)	Force (*N*)
90^0	0	80	80
70^0	25	80	60
55^0	50	80	40
45^0	90	80	20

Vertical Cutters: The two vertical cutters are fabricated with appropriate spacing of SS wires. Similar to the horizontal cutters, guitar string adjusters are used to maintain the appropriate tension and differently coloured to easy identification (Fig.5). The wires are placed in such a way to coincide with the gaps of the vertical cutter box (Fig.7) which will cut the cubes to accurate sizes.

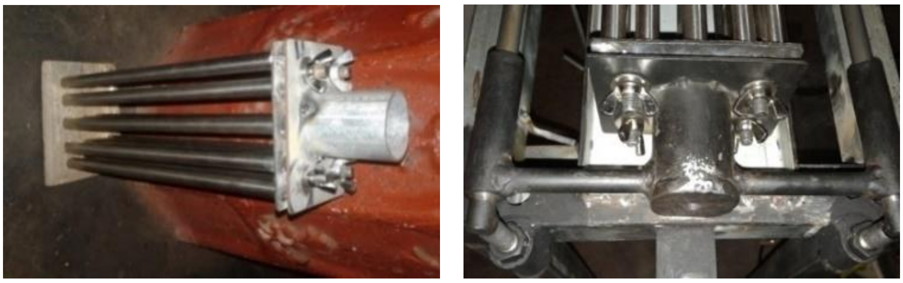


a. 3P/5P cutter b. 7P/Agalonema cutter

Fig.5. Fixed horizontals cutters

The movement of the vertical cutter is achieved by a pneumatically driven actuator attachment (Fig.7 and Fig.9). The most important aspect in the development of AFFAM was to carefully design the attachment to achieve the appropriate stroke of the actuator, and the static and dynamic balance in operation.

Actuator to Push FF block: Actuator and attachment as a unit, is made to push the FF block into the horizontal cutter imparting correct force and jerk. The actuator unit is made of 20 stainless steel pipes of gauge 16, as shown in Fig.6. Two steel shafting bars each 1*m* long, are used to obtain the movement to push the FF block.



a. Actuator **b. Actuator fixed to the machine**

Fig. 6. Actuator and fixation

Control Panel: Control panel (Fig.9) consists of micro controller board, modular relays, circuit boards, etc., used for the purpose of programming the operations and power supply unit, and trip switch and fuses are used to transfer electric energy for entire operation, while the pneumatic system controls the operations. All the printed circuit boards (PCBs) are designed and manufactured inhouse.

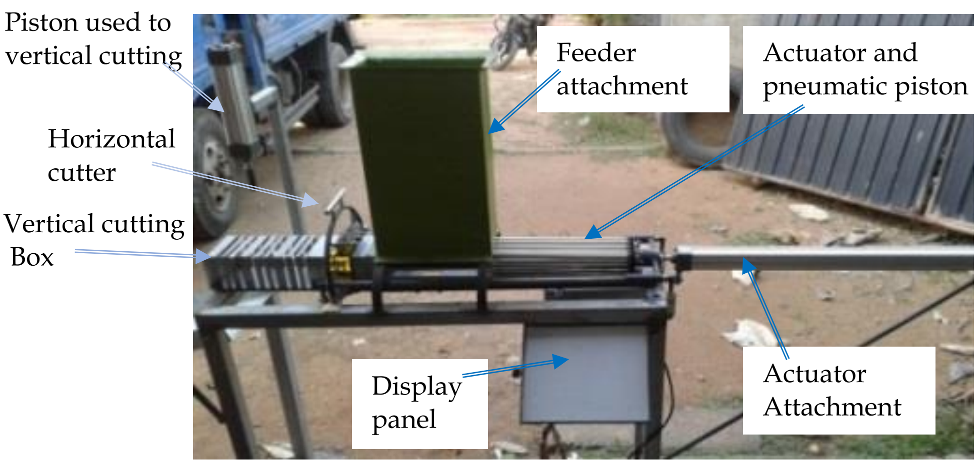


Fig.7. Actuator attachment and rest of the components at development stage

Arduino Uno has been used as the microcontroller, and 8 modular relays, LDR Sensor, circuit board, and other devices/accessories were used in automation. Exhaust fans were placed to minimize the dust deposition inside the control panel compartment.

Display Panel: The expanded view of the display panel is shown in Fig.8, which consists of pressure indicator, voltage indicator, error bulb, ON/OFF switch, start and reset switches and real time operation indicators.

Fig.8. Display panel of the machine

3.2. Developed Prototype of AFFCM

A structure is made by Zinc coded steel box bars (38 x 38 mm^2) and L shaped cross-sectioned bars (25 mm) after considering the structural integrity of the machine. A steel plate was sized and machine-bended to make the feeder compartment (Fig.9) which directs the loaded foam to cutting section in anticipated orientations.

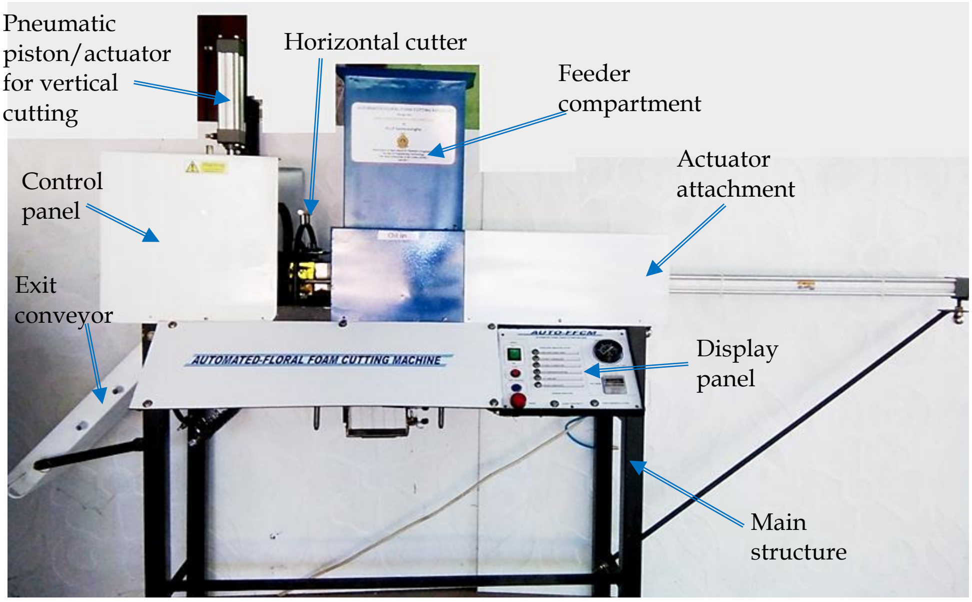


Fig.9. The final outlook of the AFFCM

Operation Sequence of the AFFCM

Five FF blocks could be accommodated in the feeder. The machine is activated when it is switched on (by ON/ OFF switch). The activation of the machine could be detected by the voltage meter on display panel. The compressor starts and triggers the pneumatic pistons/circuit. The air pressure could be checked by the pressure indicator/gauge which the optimum level is 8 bars. A pneumatic regulator is used to maintain the optimum pressure in each pneumatic piston. After attaining the correct air pressure, the Start button (on display panel) pushed on, which supplies power and activates the microcontroller and the LDR sensor sense and checked the availability of foam in the feeder. If available, the process continues, if not, it indicates the non-availability. If there are FF blocks in the feeder, the servo motors will activate and runs for around 3 *seconds* which opens the path, and the FF blocks move or rather fell into the specifically designed platform. The availability of foam in the platform is indicated by the 'floral foam feeder open' bulb in the display panel. Then a solenoid valve triggers, and a pneumatic piston activates. The relevant obstacle mechanism to restrict the motion of the FF block is also activated. The FF block is pushed through horizontal cutter to cut horizontally and then pushed into the vertical cutting box. The completion of horizontal cutting is indicated by blinking 'cutting 1 completed' blub on the display panel.

Then for vertical cutting, a signal is sent to the solenoid valve from micro control board and the movement of the vertical cutters are executed by activating the relevant pneumatic piston. The completion of vertical cutting indicates by blinking 'cutting 2 completed' blub on the display panel. This process completes in 1.5 seconds. Exhaust fans are switched on, and the dust is removed as the 'dust removing system on' bulb blinks. The exit door opens while the 'cut cube exit' bulb glows. Then the FF cubes are pushed to the basket kept outside through the exit conveyor. The pneumatic piston returns to the initial position completing one operational cycle by blinking the 'process complete' bulb along with an alarm.

The operator must reset the system/machine to start a new cycle. If the cutters are not properly located the machine will not work and it signals an 'error' and 'check horizontal cutter' starts blinking. The operator ascertains that the cutters are accurately located before starting a fresh cycle. Also, the status of presence of floral foam cubes in the feeder is indicated by the 'floral foam empty' bulb.

3.3. Comparison of the Performance of the AFFCM with the Existing Process

3.3.1. *Cutting Efficiency*

The cutting duration (average of five cycles) for four different sizes of FF cubes by existing method and by the AFFCM are given in Table 2.

Table 2 Cutting durations of existing method and new method average

Size	Existing Method (*s*)	AFFCM (*s*)	Time efficiency of AFFCM (%)
3P	16.4	3	81.71
5P	14.4	3	79.17
7P	12.5	3	76.00
Agalonema	10.4	3	71.15

As expected, there are no variations of cutting durations in AFFCM since it operates conforming to a programmed operational cycle. It is evident that smaller the cube size higher the average time taken to produce manually, whereas for the AFFCM the size does not matter. Hence higher efficiency could be obtained for smaller sizes by the AFFCM. The time efficiency varies from 71% of largest cube to 81% smallest as indicted.

3.3.2. Dust Formation and Cutting Accuracy

During the process of cutting, one of the major problems with existing method is the formation of dust. Dust collected after cutting of 10 FF blocks are given in Table 3. The results revealed that on average 69% of the dust formation or wastage can be reduced by using the AFFCM.

Table 3 Dust formation in two methods of FF cutting

Method	Quantity of Dust (*g*)
Existing method	0.166
AFFCM	0.051

Table 4 depicts the average differences (percentages) of the dimensions of FF cubes with required standard values. The differences vary from 1.5 to 19.62 with an average of 9.28 percent in the manual method. In contrast, AFFCM has 0.67 percent change resulting higher accuracy. These results are further justified by much lower SD values pertaining to AFFCM method compared to manual method.

Table 4 Cutting accuracy of two methods of FF cutting
(*Values in the parenthesis are the SD)*

	Expected Dimension (*mm*)		Percentage change from expected-Manual method	Percentage change from expected-AFFCM
3P	L	**23**	6.35 (1.05)	0.82 (0.57)
	W*	**22**	10.91 (1.12)	4.10 (0.63)
	H	**20**	1.50 (1.23)	0.69 (0.45)
5P	L	**23**	5.57 (0.70)	0.16 (0.44)
	W	**22**	10.64 (0.75)	0.41 (0.41)
	H	**27**	6.44 (0.75)	0.48 (0.43)
7P	L	**33**	10.24 (0.94)	0.34 (0.50)
	W	**22**	13.00 (0.83)	0.48 (0.52)
	H	**27**	7.48 (0.93)	0.08 (0.42)
Agalonema	L	**33**	10.24 (0.72)	0.00 (0.40)
	W	**37**	19.62 (0.66)	0.07 (0.42)
	H	**27**	9.33 (0.64)	0.41 (0.47)
Average			**9.28**	**0.67**

3.3.3. Cost of Manufacturing and Effectiveness of AFFCM

Cost of Manufacturing

The cost to manufacture per machine locally, which covers purchasing of components such as, microcontroller, programming, pneumatics system, etc., workmanship and materials with 10% contingency as estimated, is approximately SLR 140,000.00 compared to the lowest internationally tagged price of SLR 600,000.00 (approximately, USD 3000).

Operation and Maintenance Cost

The Mike Flora International (PVT) Ltd is producing FF cubes from around 58,000 FF blocks per month as given in Table 5 (from an interview with Mr. WMHD Weerakoon, Supervisor, Nursery Management, Mike Flora (Pvt) Ltd). The requirement of man days and the incurred costs are also given in Table 5, which calculated as if the daily wage rate is SLR 1,000.00 per person and an individual person works 8 hours per day. For AFFCM the time required for cutting blocks does not vary with the size of the cubes and total labor cost per month was calculated as SLR 60,41.67. In contrast to the existing manual method the labor cost incurred in AFFCM was SLR 28,965.28 saving SLR 22,923.61 per month. Even with an assumed overhead (mainly for electricity and, wear and tear) of SLR 5,000.00 per month, it is worthwhile to use mechanization over the manual method, by which the capital cost can be recovered within eight months (payback period is 7.67 months). The payback period would be further reduced if the cost saved by reduction of wastages is considered for the calculation.

Table 5 Operation and maintenance cost

Cutting method	Cutting time required (*s/block*)	Micro Flora Requirement (*blocks/month*)	Labour hour requirement	Labour cost at SLR 125/*hr.* (*SLR/month*)
Existing method	16.4	25,000	113.89	14,236.11
	14.4	15,000	60.00	7,500.00
	12.5	10,000	34.72	4,340.28
	10.4	8,000	23.11	2,888.89
	Total	**58,000**		**28,965.28**
AFFCM	3	58,000	48.33	6,041.67

4 CONCLUSIONS

The AFFCM was designed and developed after a detailed investigation to improve the productivity and product accuracy of the FF cubes which are comparable with FF blocks. The designed and developed AFFCM can be manufactured at a cost of SLR 137,453.00, which is relatively inexpensive when compared with those available in the international market, which a machine with minimum features would cost around US$ 3,000 (more than SLR 600,000). It is worthwhile to note that the as far as the features, productivity, product accuracy, etc., are concerned of the proposed AFFCM is superior and it can comfortably compete in the market. The AFFCM saves 71% to 80% (depending on block size) time than the existing method and could produce four sizes of FF cubes with higher accuracy, less wastage and minimum dust formation. This machine could reduce the labour cost by almost 80% and therefore the capital cost of the machine can be recovered within eight months of operation. The manufactured AFFCM can be commercialized with the assistance of an investor.

5 ACKNOWLEDGEMENTS

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REFERENCES

De Silva, P.D. (2014). Sri Lanka could be a regional leader in floriculture exports: Daily FT e-paper.http://www.ft.lk/agriculture/srilanka-could-be-a-regional-leader-infloriculture-exports-prof-ranjithsenarathne/31-265076

Dhanasekera, D.M.U.B. (1998). Cut flower production in Sri Lanka. Food and Agriculture Organization of the United Nations Publication.

Export Development Board (EDB). (2019). Future Potential of Floriculture Industry in Sri Lanka. http://www.srilankabusiness.com/ blog/floriculture-in-sri-lanka.html

Profitability of floriculture. Daily News e-paper. (2017). http://www.dailynews.lk/2017/04/07/business/112712/profitability-floriculture.

Rathnayake, S. and Rathnayake, S.J. (2019). An Overview of Upcountry Cut Flower Industry, Sri Lanka. Asian Journal of Agricultural Extension, Economics & Sociology 33(1): 1. DOI: 10.9734/ajaees/2019/v33i130167

https://www.alibaba.com/showroom/floral-foam-cutting-machine.html

https://en.dtfirm.com/product/69.html

https://www.made-in-china.com/showroom/huiyalichee/product-detailTSbxAaVUutpv/China-Wet-Floral-Foam-Cutting-Machine.html

https://everen.en.alibaba.com/search/product?SearchText=cutting%20machine