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Modification and performance evaluation of battery-operated brush cutter

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Abstract
This research focuses on the modification and performance evaluation of a battery-operated brush cutter, aiming to enhance cutting efficiency. modifications of a brush cutter Was carried out by replacing belt pully system with suitable size of gear box. Various motor speeds and blade types were used to evaluate the cutter's efficiency. The effects of blade type, motor speed, and cutting height on efficiency were assessed in field experiments, while laboratory tests evaluated for battery charging/discharging and motor performance under load and no-load situations. Field trials demonstrated that the three-point blade, operating at 9000 rpm with a 30 mm cutting height, achieved the highest cutting efficiency of 97.78 per cent and a uniformity coefficient of 97.49 per cent. The optimization analysis confirmed these parameters as optimal for the brush cutter's performance. The results indicate that the modified battery-operated brush cutter is highly effective. The study concludes that the optimized brush cutter offers a promising solution for grass species such as Indian copper leaf, chickweed, *Parthenium hysterophorus*, and sickle pod grass, providing excellent cutting efficiency and uniformity performance.

Keywords: Battery-operated, brush cutter, types of blades, ANOVA, cutting efficiency

1. Introduction

India's agricultural sector, which employs millions of people and makes a substantial contribution to the country's GDP, is the backbone of its economy. However, farmers still face the ongoing problem of managing weeds, which depletes valuable resources and reduces output (Magar *et al*., 2010) [4]. Despite their effectiveness, traditional engine-powered lawn cutters have a significant negative impact on the environment because to their loud noises and harmful emissions (Sanket *et al*., 2016) [2]. But in the middle of this lush battlefield, a silent revolution is taking place.

The battery-powered brush cutter is a revolutionary invention that has the potential to revolutionise weed eradication in India's varied agricultural landscapes. With zero emissions and little disturbance, these small, easy-to-use gadgets employ renewable energy to cut through weeds and grass (Magar *et al*., 2010) [4]. outfitted with various cutting tools, ranging from three-point

This research paper delves into the transformative potential of battery-powered brush cutters, exploring their design, performance and broad implications for India's agricultural future. By embracing this innovative technology, farmers can cultivate a greener, more prosperous tomorrow, one weed-free field at a time.

2. Materials and Methods

The methodology employed for the modification and performance evaluation of a battery-operated brush cutter is discussed below. The machine was fabricated in the workshop in Akola. The research and performance evaluation were conducted in the field in the Department of Farm Power and Machinery, College of Agricultural Engineering and Technology and Smriti Kendra, Dr. PDKV, Akola.

2.1.1 Selection of DC motor and battery
A 24 V DC motor was used to rotate the blade. According to the power requirement, a 500 W DC motor was selected. The DC motor was fitted in the middle of the brush cutter. A compact size, rust-proof, easy-to-clean and maintained motor with low electric consumption was used in the study.

To determine the one to use, consideration was given to the voltage and the ampere-hour rating. Since the motor is 24 V and 500 W. Hence, two sets of 12 V batteries were selected.

2.1.2 Speed controller
The DC motor speed controller enables the control of the direction of a DC motor by utilizing a Pulse-Width Modulated (PWM) DC voltage with a duty cycle that can be fully adjusted from 10 to 100 per cent. This speed controller can supply a continuous current of 25 A to the DC motor. Additionally, the circuit includes a 30 A fuse to protect against reverse polarity connections of the power supply and control voltage.

2.1.3 Gear type gearbox
A brush cutter's gearbox is essential for transforming battery power into the rotational force required to move the cutting blade. It is located where the cutting head and drive shaft meet and ensures efficient power transfer. The gearbox has an important effect on cutting speed, torque and overall performance, which helps the brush cutter efficiently handle different grass types. With a 1:4 gearbox ratio, it enhances torque and increasing output speed. Power is supposed to travel from the motor to the gearbox and finally to the output.

2.1.4 Main frame
The frame that supported it was built with a mild steel angle that dimensions 25 mm by 25 mm by 2 mm. This selection was chosen for the steel's strength, stress-reduction ability and durability. The gear box assembly was connected to the frame, which was secured to the chassis at a height of 250 mm above the ground.

2.1.5 Diagram of a modified battery-operated brush cutter
The battery-operated brush cutter comes with a DC motor, inner and outer shafts, a battery, a speed controller, a gear-type gearbox, rubber tires, a coupler and wires or cutting blades. Considerations for the blade design were the forces operating on the blade and the force needed to cut grass. Cutting grass with a sharp blade uses less than 10 Newtons of force, depending on the height, density and area covered. As a result, the blade was made to require more than 10 Newtons to cut well. Because stainless steel is lightweight and durable, it can match the motor speed with little loss of friction.

Conceptual design calculations were the first step in the modification process and then a conceptual diagram was developed to direct manufacture and assembly.

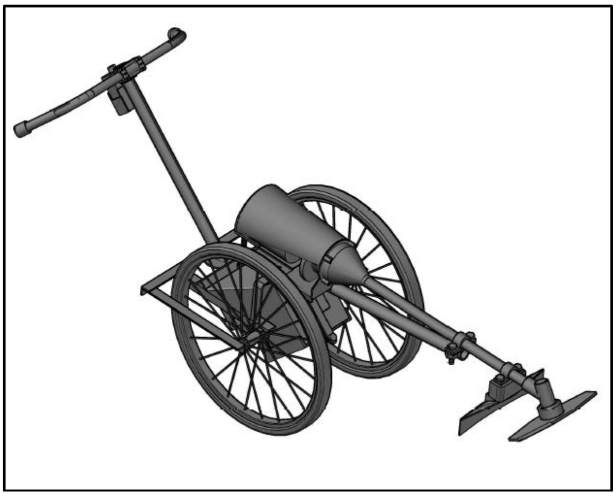

Fig 1: Modified battery-operated brush cutter

2.3 Performance evaluation
2.3.1 Charging and discharging behavior of battery-operated brush cutter
The time interval for charging was calculated by measuring the time interval between the time of full discharge and the time of wholly charged condition. The various parameters, like battery voltage and battery current, were measured at intervals of 30 minutes. The battery was charged till it reached up to 24 V.

The fully charged battery was discharged by operating the brush cutter in loaded and unloaded condition in the field. Various parameters like time, battery voltage, battery current, and discharge rate were measured at an interval of 15 minutes. The voltage reduction was noted until the battery was completely discharged, which indicated that the DC motor was completely switched off and suddenly stopped working.

2.3.2 Measurement of different field performance Parameters
The field performance of a battery-operated brush cutter was evaluated to determine the effective cutting operation. The following parameters were calculated during the trial, and the most suitable parameter was found.

2.3.2.1 Cutting efficiency
Cutting or functional efficiency was assessed by clearing grass from a 1 m x 1 m area. Before starting the cutting operation, weeds were identified and documented. This procedure was repeated at five random spots across the field. Cutting efficiency was calculated using the following formula (Mehta *et al*., 2010) [4].

$$E_c\,(\%) = \frac{N_1 - N_2}{N_1} \times 100$$

where,
E_c = Cutting efficiency (%)
N_1= Number of weeds counted before cutting (m^2)
N_2= Number of weeds counted after cutting (m^2)

2.3.2.2 Uniformity coefficient
The uniformity coefficient was determined by summing the deviations of the grass cutting height from the desired cutting height, dividing this total by the number of measurement locations and multiplying by the grass cut's height. This coefficient was calculated using the following formula (Mehta *et al*., 2010) [4].

$$C_u = \frac{S}{N \times H}$$

where,
S = Sum of deviation of height of cut with respect to desired height of cut
N = No. of location
H = Height of cut

2.3.2.3 Effective Field Capacity
It is the actual area the machine covers based on its total time consumed and width. Effective or actual field capacity was given by the following formula (Mehta *et al*., 2010) [4].

$$E.F.C = \frac{A}{T_p + T_e}$$

where,
E.F.C.= Effective field capacity (ha/h)
A = Area covered (ha)
T_p= Productive time (h)
T_e = Non-productive time (h) (time lost for turning and cleaning blades when clogged with grass)

2.3.2.4 Theoretical Field Capacity
Theoretical field capacity is the rate of field coverage of the machine that would be obtained if the machine was performing its function 100 per cent of the time at the rated speed and always covered 100 per cent of its width and calculated by following formula. (Mehta *et al*., 2010) [4].

$$T.F.C. \text{ (ha/h)} = \frac{S \times W}{10}$$

where,
T.F.C. = Theoretical field capacity (ha/h)
S = Speed of operation (km/h)
W = Theoretical cutting width (m)

2.3.2.5 Field Efficiency
The field efficiency was calculated by taking the ratio of actual field capacity to theoretical field capacity. Field efficiency is expressed in per cent and is given by the following formula. (Mehta *et al*., 2010) [4].

$$\text{Field efficiency (\%)} = \frac{Effective\ field\ capacity}{Theoretical\ field\ capacity} \times 100$$

2.3.2.6 Moisture content
Moisture content is measured by comparing the initial and final weights of a cut grass stalk sample that has been placed in an oven until it reaches complete or optimum moisture content. Moisture content is calculated using the following formula: (Mehta *et al*., 2010) [4].

$$\text{Moisture content (\%)} = \frac{intial\ weight\ of\ sample - final\ weight\ of\ sample}{initial\ weight\ of\ sample} \times 100$$

2.4 Statical Data analysis
A statistical analysis was conducted to evaluate the effect of operational parameters on brush cutter performance using a 4 × 3 factorial randomized block design and factorial ANOVA. The independent variables were motor speed (RPM), blade type and cutting height, while the dependent variables, cutting efficiency and uniformity coefficient, were performance indicators. Two-way ANOVA was used to assess interactive effects, with significance levels reported.

3. Results and Discussion
3.1 Field performance evaluation of battery-operated brush cutter
The battery-operated brush cutter's field performance was assessed under optimal conditions at the Department of Farm Power and Machinery and CRS, Dr. PDKV, Akola. Figure 2 depicts the field before and after the cutting process using the battery-operated brush cutter.

Fig 2: View of the field before and after cutting operation on the field

3.2 Effect of operational parameters on cutting efficiency
Figure 3 shows that the 3-point blade had the highest cutting efficiency at a cutting height of 20 mm, measuring 96.78 per cent at 9000 rpm and 93 per cent at 6000 rpm. The lowest cutting efficiency was 90.61 per cent at a motor speed of 3000 rpm. With a cutting efficiency of 84.61 per cent at 3000 rpm, 87.25 per cent at 6000 rpm and 90.58 per cent at 9000 rpm, the 2-point blade had the lowest cutting efficiency. At 3000, 6000 and 9000 rpm, the round blade's cutting efficiency was 87.24, 88.87 and 91.91 per cent, respectively. The cutting efficiency of the nylon wire was 87.66, 88.84 and 94.13 per at the speed of 3000, 6000 and

9000 rpm respectively.

Table 1 shows the results of a statistical evaluation of both the separate and combined impacts of operational parameters on cutting efficiency. At the 1 and 5% levels of significance, it was found that the cutting efficiency was considerably impacted by the kind of blade (l) and motor speed (ll) at a cut height of 20 mm. Each variable also had an impact on cutting efficiency. As seen in Figure 2.

As seen in Figure 4, the 3-point blade showed the best cutting efficiency at a cutting height of 30 mm, with 97.78 per cent at 9000 rpm and 94.97 per cent at 6000 rpm. The lowest cutting efficiency recorded was 92.25 per cent at 3000 rpm. With 86.16 per cent cutting efficiency at 3000 rpm, 87.87 per cent at 6000 rpm, and 90.42 per cent at 9000 rpm, the 2-point blade had the lowest cutting efficiency. At 3000 rpm, 91.87 rpm and 9000 rpm, the round blade's cutting efficiency was 89.94, 91.87 and 93.84 per cent, respectively. The cutting efficiency of the nylon wire at motor speeds of 3000, 6000 and 9000 rpm was 88.24, 89.95 and 91.36, respectively.

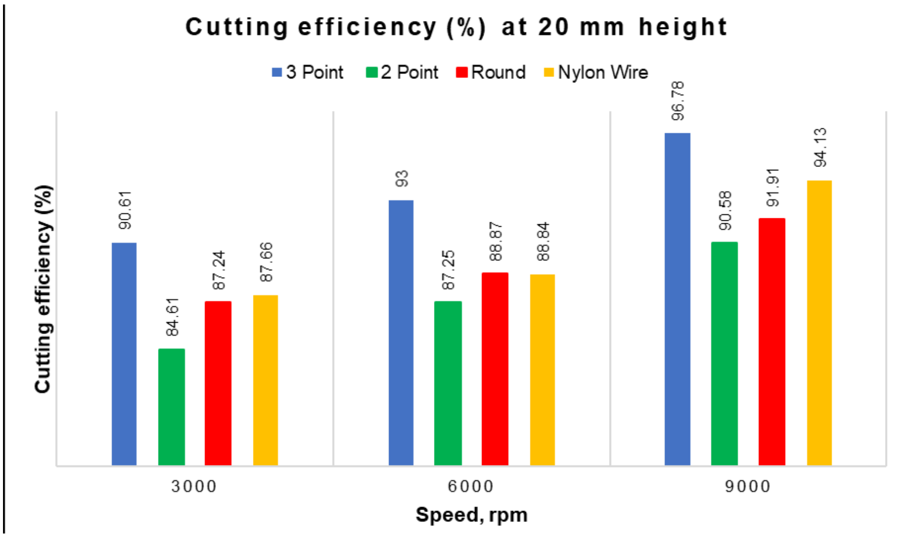

Fig 3: Cutting efficiency (%) at 20 mm height

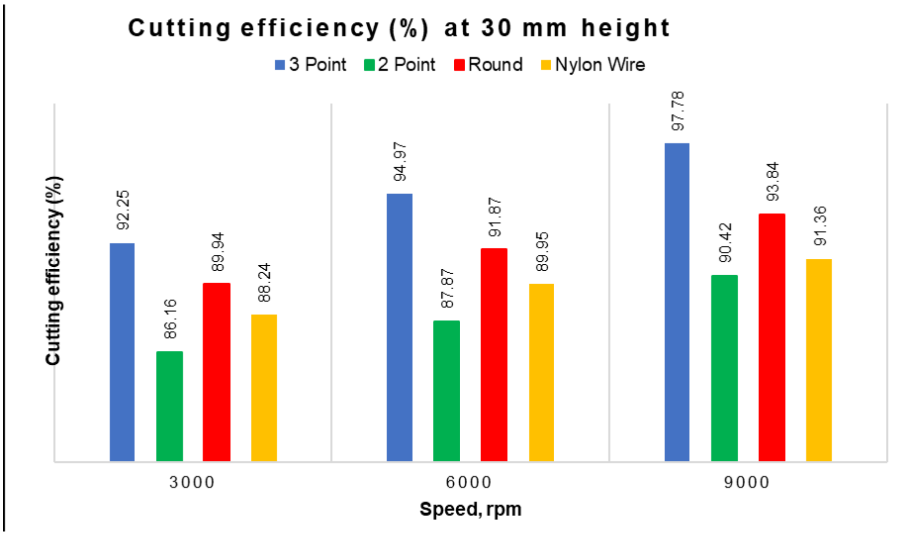

Fig 4: Cutting efficiency (%) at 30 mm height

Table 1: ANOVA for the combined effect of type of blade and speed of motor on cutting efficiency at 20 mm height

Source of Variation	DF	SS	MSS	F Cal	F Tab (5%)	F Tab (1%)
Replication	4	6.12	1.53	0.45	2.58	3.78
Treatment	11	642.36	58.40	17.14	2.01	2.68
Factor A	3	281.18	93.73	27.50	2.82	4.26
Factor B	2	350.77	175.39	51.47	3.21	5.12
A X B	6	10.41	1.73	0.51	2.31	3.24
Error	44	149.94	3.41			
Total	59	798.42				

	A X B	Factor A	Factor B
S.Em ±	0.83	0.48	0.41
CD or LSD	2.35	1.36	1.18
Test of significance (p=0.05)	S	S	S
CV	2.05		

Table 2: ANOVA for the combined effect of type of blade and speed of motor on cutting efficiency at 30 mm height

Source of Variation	DF	SS	MSS	F Cal	F Tab (5%)	F Tab (1%)
Replication	4	7.68	1.92	1.11	2.58	3.78
Treatment	11	596.70	54.25	31.31	2.01	2.68
Factor A	3	396.24	132.08	76.22	2.82	4.26
Factor B	2	191.52	95.76	55.26	3.21	5.12
A X B	6	8.93	1.49	0.86	2.31	3.24
Error	44	76.24	1.73			
Total	59	680.62				

	A X B	Factor A	Factor B
S.Em ±	0.59	0.34	0.29
CD or LSD	1.68	0.97	0.84
Test of significance (p=0.05)	S	S	S
CV	1.45		

3.3 Effect of operational parameter on uniformity coefficient

At two different heights of 20 mm and 30 mm, the uniformity coefficient for each of the four blade types was measured and recorded; outcomes are provided in Appendix F.

Figure 5 indicates that the 3-point blade showed the best uniformity at a height of cut of 20 mm, with a uniformity coefficient of 95.76 per cent at a motor speed of 9000 rpm, 91.80 per cent at 6000 rpm, and a minimum uniformity coefficient of 87.72 per cent at 3000 rpm. At 3000, 6000 and 9000 rpm, the 2-point blade's uniformity coefficient was determined at 89.67, 91.98 and 94.40 per cent, respectively. It was determined that the round blade's uniformity coefficient was 89.34 per cent at 3000 rpm, 95.03 per cent at 6000 rpm, and 95.09 per cent at all rpm. The uniformity coefficients of the nylon wire were 89.46, 90.82 and 94.32 per cent at 3000, 6000 and 9000 rpm respectively.

Figure 6 shows that the 3-point blade exhibited the highest uniformity at a height of cut of 30 mm, with a uniformity coefficient of 97.49 per cent at 9000 rpm, 94.39 per cent at 6000 rpm and a minimum uniformity coefficient of 93.31 per cent at 3000 rpm. The 2-point blade's uniformity coefficient was determined at 3000, 6000 and 9000 rpm and was 91.47, 92.46 and 95.01 per cent, respectively. The round blade's uniformity coefficient was found to be 90.14 per cent at 3000 rpm, 94.24 per cent at 6000 rpm and 97.14 per cent at 9000 rpm. The uniformity coefficient of the nylon wire was 93.16, 93.40 and 95.94 per cent at motor speed of 3000, 6000 and 9000 rpm respectively.

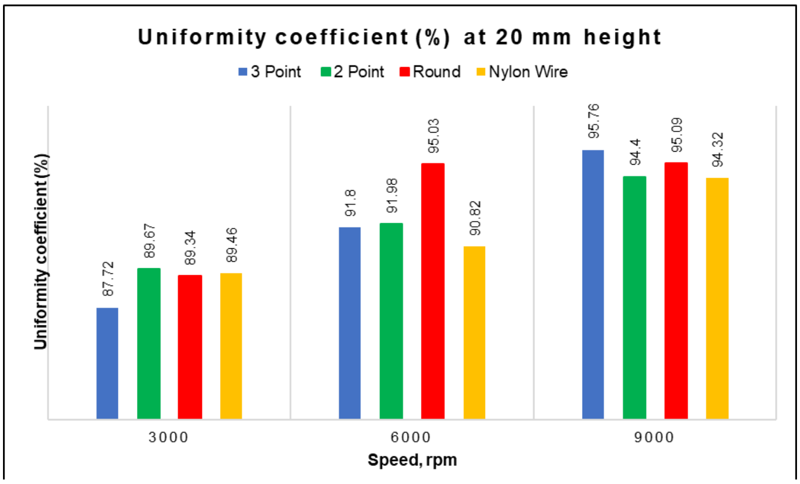

Fig 5: Uniformity coefficient (%) at 30 mm height

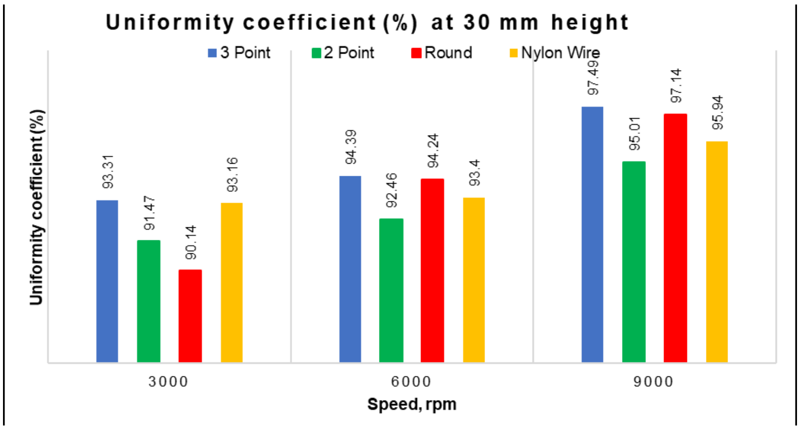

Fig 6: Uniformity coefficient (%) at 30 mm height

Table 3: ANOVA for the combined effect of type of blade, speed of motor on uniformity coefficient at height of 20 mm

Source of Variation	DF	SS	MSS	F Cal	F Tab (5%)	F Tab (1%)
Replication	4	12.76	3.19	0.40	2.58	3.78
Treatment	11	412.85	37.53	4.70	2.01	2.68
Factor A	3	23.34	7.78	0.97	2.82	4.26
Factor B	2	344.03	172.02	21.54	3.21	5.12
A X B	6	45.48	7.58	0.95	2.31	3.24
Error	44	351.37	7.99			
Total	59	776.98				

	A X B	Factor A	Factor B
SE(m) ±	1.26	0.73	0.63
CD or LSD	3.60	2.08	1.80
Test of significance (p=0.05)	S	NS	S
CV	3.07		

Table 4: ANOVA for the combined effect of type of blade, speed of motor on uniformity coefficient at height of 30 mm

Source of variation	DF	SS	MSS	F Cal	F Tab (5 per cent)	F Tab (1 per cent)
Replication	4	19.82	4.96	0.79	2.58	3.78
Treatment	11	261.06	23.73	3.80	2.01	2.68
Factor A	3	33.35	11.12	1.78	2.82	4.26
Factor B	2	195.75	97.87	15.65	3.21	5.12
A X B	6	31.97	5.33	0.85	2.31	3.24
Error	44	275.12	6.25			
Total	59	556.00				

	A X B	Factor A	Factor B
S.E(m) ±	1.12	0.65	0.56
CD or LSD	3.19	1.84	1.59
Test of significance (p=0.05)	S	NS	S
CV	2.66		

3.4 Cutting efficiency
Based on calculations, the battery-operated brush cutter's cutting efficiency varied between 84.61 to 97.78 per cent. Trial 1, Trial 2 and Trials 3, all three measurements were collected at five different locations.

3.5 Theoretical field capacity
Battery-operated brush cutters were found to have an average theoretical field capacity of 0.081 ha/h. The brush cutter's theoretical field capacity is dependent on its operating speed and theoretical width.

3.6 Effective field capacity
The effective field capacity was determined by taking into account both the productive and non-productive time needed for the brush cutter to operate in the field. The brush cutter's effective field capacity was determined to be 0.076 ha/h.

3.7 Field efficiency
Field efficiency was calculated from the values of theoretical field capacity and effective field capacity. The average field efficiency of the brush cutter was found to be 93.82 per cent.

4. Summary and Conclusion
Modification and performance evaluation and modifications of a battery-powered brush cutter Was carried out by replacing belt pully system with suitable size of gear box. Various motor speeds and blade types were used to evaluate the cutter's efficiency. The effects of blade type, motor speed, and cutting height on efficiency were assessed in field experiments, while laboratory tests evaluated for battery charging/discharging and motor performance under load and no-load situations.

The results indicated that blade type and motor speed had the greatest influence on cutting efficiency. The 3-point blade performed the best, with a cutting efficiency of 97.78 per cent at 9000 rpm at a 30 mm cutting height, resulting in lower consumption of energy and cut time. Optimization revealed that the ideal parameters—3-point blade, 9000 rpm motor speed, and 30 mm height—achieved 97.78 per cent cutting efficiency and 97.49 per cent uniformity coefficient, showing the cutter's efficiency.

Uniformity coefficients were evaluated at motor speeds of 3000, 6000 and 9000 rpm at cutting heights of 20 mm and 30 mm. The 3-point blade achieved the highest uniformity of 97.49 per cent at 30 mm height and 9000 rpm. Statistical research revealed that blade type and motor speed had an important effect on uniformity.

Field studies showed a cutting width of 800-960 mm, an average field capacity of 0.045 ha/h and a theoretical field capacity of 0.047 ha/h, all with a field efficiency of 96.29 per cent. The average cutting efficiency was 97.03 per cent and uniformity was 97.22 per cent.

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