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Development and Performance Evaluation of Battery Operated Portable Tree Pruning Device

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A B S T R A C T

Pruning is practiced in ber to enhance productivity of the trees and to improve the quality of fruits. Through the pruning operation, the almost unproductive upper part of the past season's main shoots and its secondary branches as well as undesirable and broken branches are removed so that the most healthy and vigorous growth is induced at the most productive nodes. Due to the high cost and declining availability of skilled labour and the safety issues in the manual pruning, alternative solutions for pruning fruit trees is becoming essential. For the experiment, the developed pruner had pruning capacity 0.0222 cuts/second for ber. The traditional method of pruning had pruning capacity 0.0186 cuts/second for ber. The average time taken to cut dry and wet branches by developed pruner was 24.85 seconds and 25.85 seconds, respectively. The values of physiological response (heart rate, energy expenditure rate and oxygen consumption rate) were low as compare to traditional pruner which indicated that the developed pruner is ergonomically safer to use. The operation cost of developed pruner was economically feasible as compared to traditional method of pruning.

Introduction

Pruning is practiced in ber to enhance productivity of the trees and to improve the quality of fruits. Through the pruning operation, the almost unproductive upper part of the past season's main shoots and its secondary branches as well as undesirable and broken branches are removed so that the most healthy and vigorous growth is induced at the most productive nodes. The productivity of the tree is thus maintained because about 98 % of the fruits produced on any pruned branches are borne on vigorous shoots, and only 2 % on the other shoots. In an old ber orchard, the trees develop a crowded crown with overlapping branches which shade each other and push most of the fruit bearing area onto the exterior of the crown away from the tree trunk. Early pruning has been observed to

advance flowering and fruit maturity.

Pruning is one of the most important tree maintenance practices that should not be ignored because it gives a big impact on tree's health and structure (Clark and Matheny, 2010). By removal of diseased, broken or dead branches on mature trees and young trees, it will protect the trees by preventing decay-producing fungi from penetrating and infecting other areas of the tree (Gilman and Grabosky, 2006). Pruning prevents excessive fruiting, overcrowding, disease spreading which increases fruit size, total soluble solids, better coloration, facilitates light penetration in to the interior of the tree canopy. Tree pruning is a necessary task that assists in maintaining healthy, structurally sound and aesthetically pleasing trees. Accomplishing this objective requires proper methods, techniques and tooling. Farmers and other tree professionals are continuously searching an efficient solution for their pruning needs to minimize time spent on cutting. To expose branches to light and air or to remove dead or diseased wood are necessary responsibilities of a tree professional, but the problem still remains to find a device that can perform all tasks. The main aim is to developed battery operated portable tree pruning device with a view to reduce working stress, human risk and increase pruning capacity.

Materials and Methods

The methodology was used for the design and development of battery operated portable tree pruning device for ber.

Design consideration

As a part of design consideration following Single operator can handle the device easily with minimum effort, the device was simple in design and cheaper in cost, the pruning device was light in weight, the length of pruning device was 145 to 400 cm (Telescopic light weight pipe) and the working of pruning device was easy with minimum damage to branch.

Developed battery operated portable tree pruning device

Motor

12V D.C wiper motor having a speed of 1200 rpm was used. Motor has 66 mm diameter and 130 mm length. Motor was mounted vertically on 100 mm × 70 mm × 2 mm dimensional plate by the help of clamp on telescopic pipe.

Disc or Cutter

Disc or cutter is a main part of a cutting mechanism. The disc or cutter was mounted on the shaft with help of bolt. Normally, it can be used for pruning of tree branch.

Telescopic light weight pipe

The telescopic pipe is made of hollow aluminium which consists three pipes of different diameters. It can be extendable from 145 up to imposing 400 cm. The weight of telescopic pipe is 680 g.

Battery

The capacity of the battery is 12 V and 7.2 Ah. The weight of the battery is 2 kg and it provides backup of about 3 hours. Battery is carried in a sackcloth and comfortably attached to the hip of the operator.

Torsional spring

Two plates of 100 mm × 70 mm size and a thickness of 2 mm are attached such that they can be placed at right angles to each other. The motor is attached to one plate and the telescopic pipe is attached to the other plate.

Nuts and bolts

Nuts and bolts were used in several applications, with a primary function to hold components together. Motor was clamped using nut and bolts.

Laboratory test

The design dimensions were measured in the laboratory. The working of each component like movement of cutting unit, setting of adjustable length of pipe etc. were tested. The total weight of the device was also measured.

Field test

Moisture content

Moisture content of the branch (wet and dry) was determined by standard oven drying method. Each and every sample (a piece of 2 cm from cut) was taken from the branches of different crops (Mango, Ber and Guava).

The samples were weighed and kept in different moisture boxes. Samples were kept in oven for 24 hours at the temperature of 105°C. The mass of wet and dry sample was determined and average moisture content on dry basis was calculated.

$$Moisture\ Content(d.b.) = \frac{Ww - Wd}{Wd} \times 100$$

$$Moisture\ Content(w.b.) = \frac{Ww - Wd}{Ww} \times 100$$

Where;

Ww = Weight of the wet branch, g

Wd = Weight of the dry branch, g

Height

Pruning on different crops (Mango, Ber and Guava) were conducted with different working height (145 to 400 cm) as per requirement using developed device for pruning/cutting branches.

Pruning time

Time required for pruning was measured using stopwatch. The number of cuts in particular time was calculated.

$$\text{Pruning time} = \frac{Number\ of\ cuts}{Time\ required\ for\ cutting}$$

Pruning capacity

$$\text{Pruning capacity(cuts/time)} = \frac{Number\ of\ cuts}{Time\ required\ for\ total\ cuts}$$

Where,

Time required for total cuts = Time required for cutting + Other time of pruning operation

Branch diameter

The diameter of pruned branch (dry or wet) was measured just nearby cut using digital vernier caliper.

Heart rate

The heart rate is the speed of heart beat. It was measured in heart bits per minutes. Smart watch was used for measurement of heart beat.

Oxygen consumption rate

The oxygen consumption rate is defined as the amount of oxygen consumed by the tissues of the body. It was measured in l/min. Oxeylog was used to measure oxygen consumption rate. It was calculated by the following equation.

$$Y = 0.0114\,X - 0.68$$

Where,

Y = Oxygen consumption, l/min

X = Heart rate.

Energy expenditure rate (kJ)

Energy expenditure was computed by using calorific value of 20.93 kJ/l of oxygen by multiplying oxygen consumption rate during the experiment.

Cost analysis of developed device

The total pruning cost of mango, guava and ber (weight or time basis) of the developed pruner was determined considering fixed cost and variable cost with the help of straight-line method.

Pruning method

Traditional method

Traditionally pruning is done by various tools like secateurs, shears, knives and billhook. By this way, pruning operation become difficult above human height *i.e.* up to about 160 cm height of plant. This method is very time consuming and many times hands get injured because of some thorny plants.

Developed device method

To overcome the limitations regarding traditional pruning methods, a battery-operated portable pruning device was developed. The device is easy to operate and capable of pruning from 145 cm to 400 cm height in compare with traditional tools *i.e.* up to human height 160 cm. The device was found simple, handy, light weight and can be used safely and efficiently by a single person with minimum losses. The developed device start the cutting by switch on and off button mode. Before switching the device on one has to put disc or cutter on the selected branch (dry/wet). The developed device cuts branches gently and switch off the device after completion of cutting/pruning.

Results and Discussion

Performance evaluation

The performance of the developed pruner was determined in terms of diameter of branch (wet and dry cut), moisture content of branch (wet and dry cut), pruning capacity, physiological response (heart rate, oxygen consumption rate and energy expenditure rate) on ber crop. The results were compared between developed method and traditional method. Also, the cost economics was carried out.

Diameter of branch cut (Dry or dead)

The pruning of dry branch of ber tree was carried out by two different methods. In developed device method average time taken to cut dry branches were 24.85 seconds for an average diameter of 12.78 mm. While, in traditional method average time taken to cut dry branches were 2.80 seconds for an average diameter of 12.56 mm.

Diameter of branch cut (Wet or live)

The pruning of wet branch of ber tree was carried out by two different methods. In developed device method average time taken to cut wet branches were 25.85 seconds for an average diameter of 11.27 mm. While, in traditional method average time taken to cut wet branches were 2.65 seconds for an average diameter of 11.44 mm. The time taken by developed method seems more as compare to traditional method. It may be due to the

amount of force by rotating motor and the impact force supplied by a human being.

The rate of entry of the blade is governed by the speed of motor and size of saw, which is limited by battery power and the material cut by means of rotation of blade.

Therefore based on the depth achieved slowly and slowly operator has to go on increasing the depth and in this way the cut propagates whereas in case of traditional method (shear action or impact force) the amount of force applied is always on higher side and so the cut takes in one instance only.

Moisture content of branch cut (Dry or dead)

In developed device method average time taken to cut dry branches owing dry basis moisture content (101.96%) and wet basis moisture content (49.36%) found 24.85 seconds. Whereas, in traditional method average time taken to dry cut branches owing dry basis moisture content (110.14%) and wet basis moisture content (51.65%) found 2.80 seconds.

Moisture content of branch cut (Wet or live)

Moisture content of the material cut was determined using oven dry method for both the material is cut by the developed device and that cut by traditional method. In developed pruner average time taken to cut dry branches owing dry basis moisture content (131.74%) and wet basis moisture content (56.42%) found 25.85 seconds.

Whereas in traditional method, average time taken to dry cut branches owing dry basis moisture content (126.69%) and wet basis moisture content (55.64%) found 2.65 seconds. Moisture content (wet basis) of wet and dry branches considered during pruning operation, traditional method take less time as compared to developed method.

Similarly, pruning of dry branch take less time as compared to wet branch. While cutting wet/live branches it was noted that cutter slips and stuck on the surface.

Pruning capacity

The pruning capacity observed were 0.0222 and 0.0186 cuts/s by developed pruner and traditional method, respectively.

The pruning capacity of the developed device was more as compared to the traditional method. It was due to the increased reach of the human labour by the device. By the developed device the branch could be pruned from a tree up to the height of 400 cm with comfort and safely without any injury.

Physiological response

Physiological responses were analysed using heart rate, energy expenditure and oxygen consumption rate. For ber in developed device method, average heart rate 77.50 bits/min, average energy expenditure rate 4.26 kJ/min and average oxygen consumption rate 0.20 l/min found. Whereas in traditional method, average heart rate 80.25 bits/min, average energy expenditure rate 4.92 kJ/min and average oxygen consumption rate 0.23 l/min found. The developed device method has minimum effort, reduced muscular work and minimum risk to be injured as compared to traditional method. All the three values were higher for traditional method as compared to that of developed pruner, therefore, the developed pruner could be considered ergonomically safe.

Fig.1 Developed battery operated portable tree pruning device

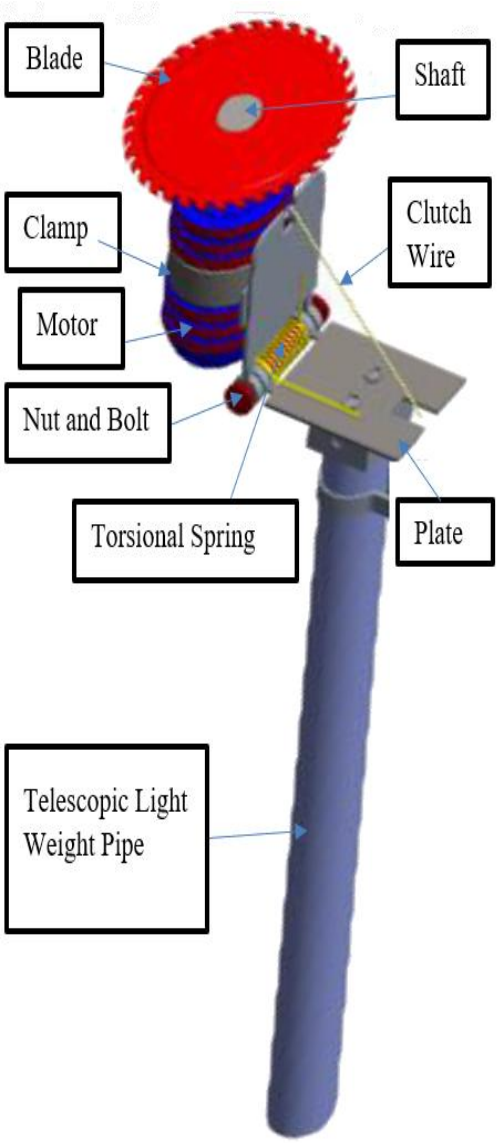


Fig.2 Diameter of branch cut (Ber tree)

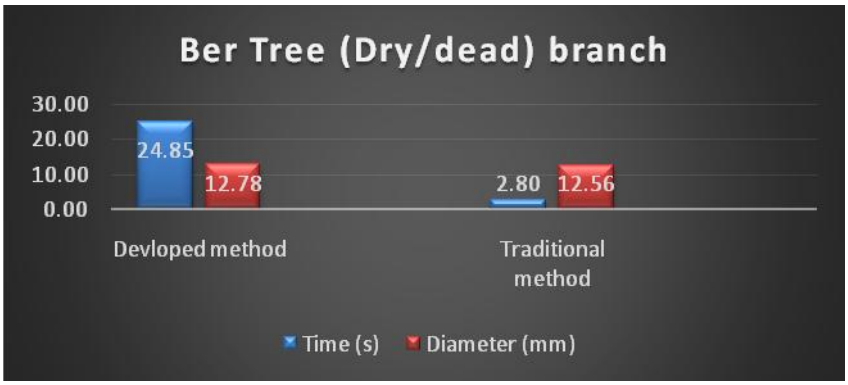


Fig.3 Diameter of branch cut (Ber tree)

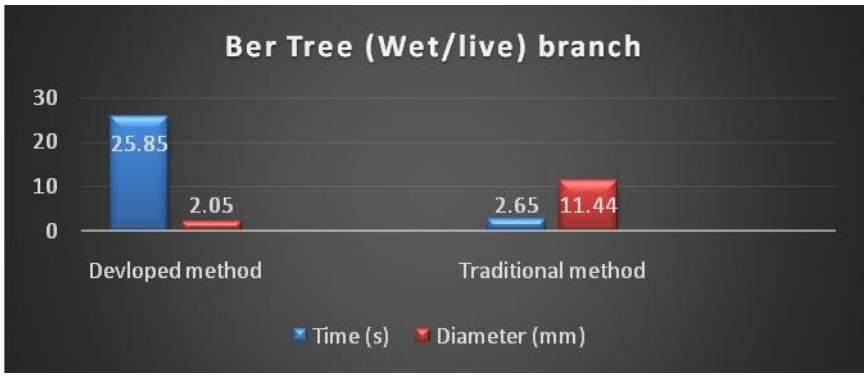


Fig.4 Moisture content of branch cut (Ber tree)

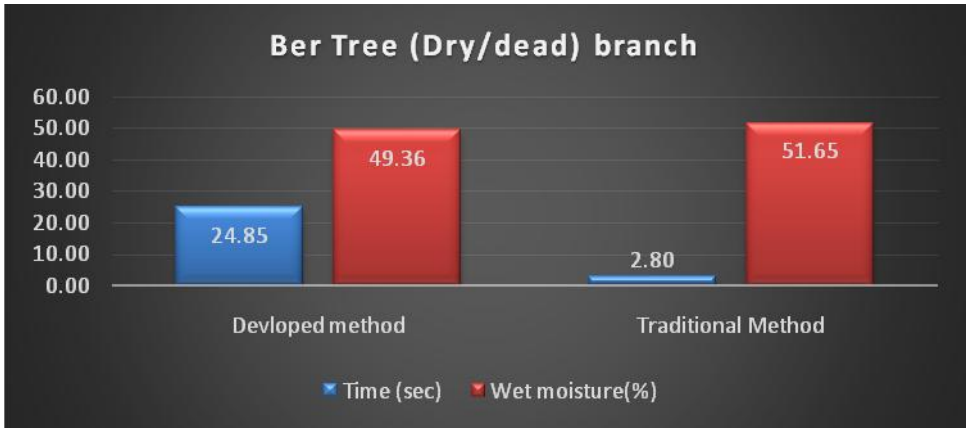


Fig.5 Moisture content of branch cut (Ber tree)

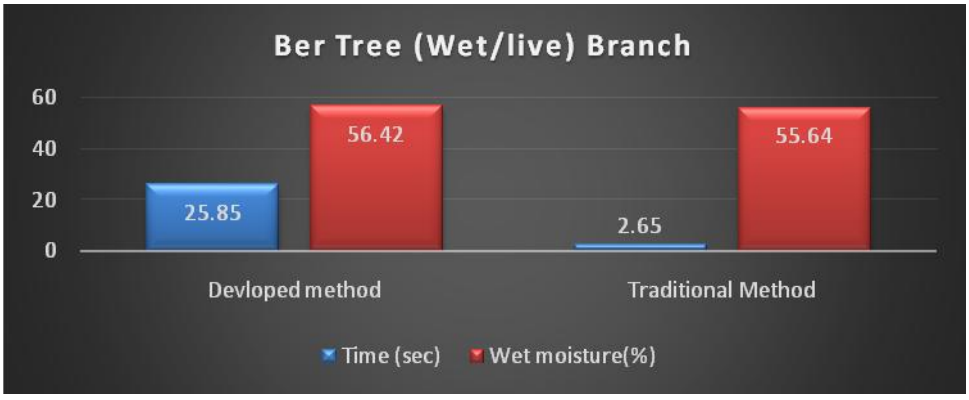


Fig.6 Pruning capacity

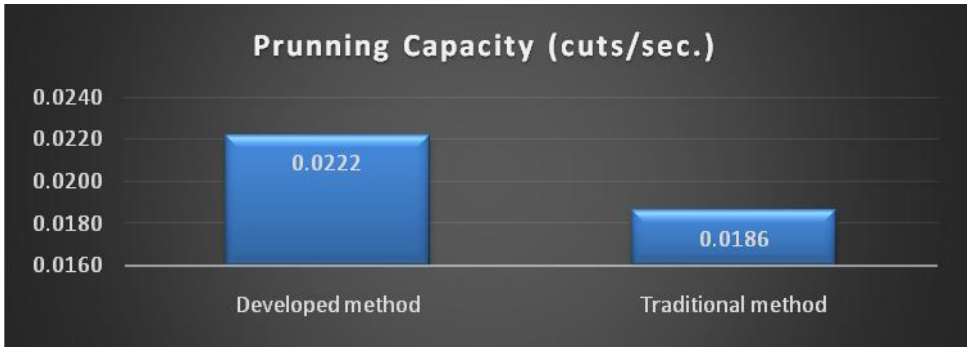


Fig.7 Heart rate and energy expenditure rate

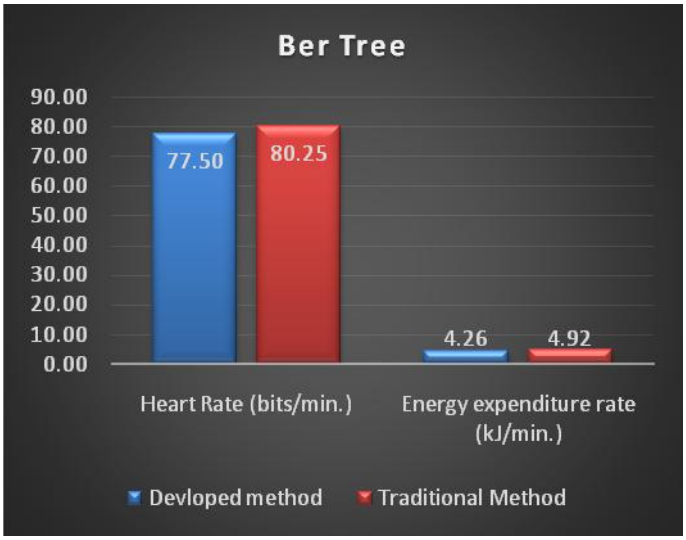


Fig.8 Oxygen consumption rate

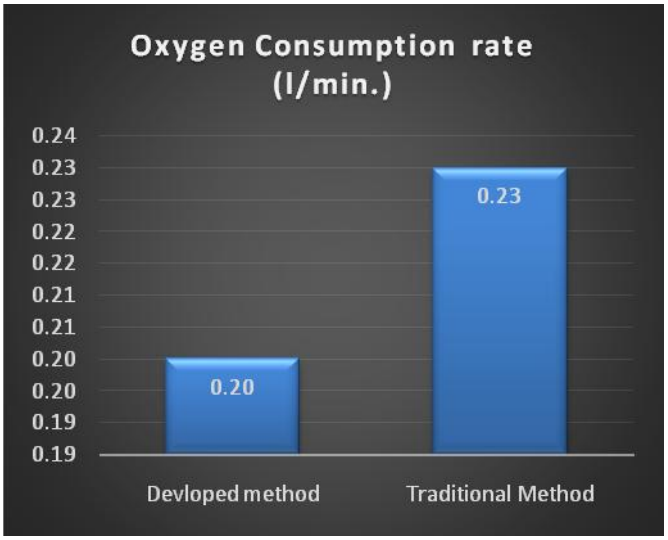
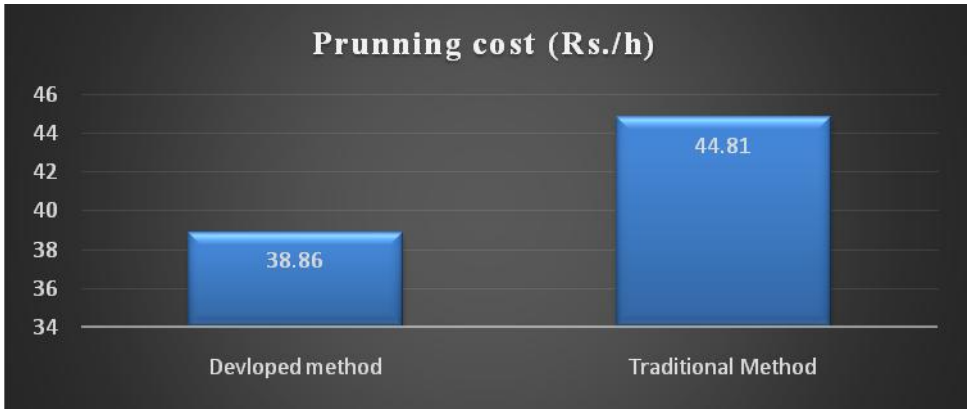


Fig.9 Cost of pruning



Cost economic

Pruning cost of ber was carried out by both the methods and the total pruning cost was determined by the straight line method. Both the methods were evaluated based on pruning cost also.

The pruning cost by developed method and traditional method were found to be 38.86 Rs./h and 44.81 Rs./h respectively. The traditional method was found more costly as compared to the developed pruner.

The developed pruner had pruning capacity 0.0222 cuts/second for ber. The traditional method of pruning had pruning capacity 0.0186 cuts/second for ber. The average time taken to cut dry branches by developed pruner was 24.85 seconds in case of ber. The average time taken by developed pruner to cut wet branches was 25.85 seconds for ber.

The values of physiological response (heart rate, energy expenditure rate and oxygen consumption rate) were low as compare to traditional pruner which indicated that the developed pruner is ergonomically safer to use. The operation cost of developed pruner was economically feasible as compared to traditional method of pruning.

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