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Design and Evaluation of Functional Parameters of the Double Helical Roller Cutting Mechanism for Ripened Chilli

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ABSTRACT

Chilli cultivation needs more number of labourers for harvesting apart from the usual field operations such as sowing, weeding, pesticide applications, etc. as compared to other field crops. It is harvested (picking) 2 to 4 times and these harvestings are within a short span of time to get the quality produce, otherwise market price of chilli will be reduced. Mechanization is only the way through appropriate technology need to be developed to make farmer as profitable as possible and reduce the cost of harvest. The experimental set up was designed with two double helical rollers of each length 200 cm and overall diameter 14 cm. The base frame was developed with the height of 100 cm, width of 85 cm and length of 160 cm to house the double helical rollers inside of the base frame. The rollers were fixed in the base frame inclined to the horizontal. The experimental set up was modified regarding power supply to double helical rollers, rotational speed and gap between the two rollers. The prototype ripen chilli harvester was fabricated with four numbers of adjusting gap between two rollers and four rotational speeds of double helical rollers. The pulleys were changed on the double helical roller to get the four numbers of speeds like 289 rpm, 393 rpm, 484 rpm and 658 rpm by kept one small size of pulley on prime mover. The four numbers of gaps were provided between the two rollers as 32 cm, 33 cm, 34 cm and 35 cm.

Key words: *Chilli, Double helical roller, Harvesting, Mechanization, Sowing and Weeding,*

Chilli grows best at 20–30°C temperatures, growth and yields suffer when temperatures exceed 30°C or drops below 15°C for extended periods. The crop can be grown over a wide range of altitudes from sea level upto nearly 2100 meter. Chilli is reported to be a native of South America and is widely distributed in all countries in the world. Red Chilli is an indispensable spice in the food habits of most people in the world. Currently, chillies are used throughout the world as a spice and also in the making of beverages and medicines. Chilli has been cultivated as one of the major crops in most states of India. Chilli is believed to have been introduced to India by Portuguese explorers at Goa in 17th century. With in the short span of time, it became one of the most important crops in India. It is cultivated mostly in Andhra Pradesh, Karnataka,

Tamilnadu, Orissa, West Bengal etc. Many chilli constituents are important for nutritional value, flavour, aroma, texture and colour. Chillies are low in sodium and cholesterol free, rich in vitamin A, vitamin C, vitamin E, a good source of potassium and folic acid. Fresh green chilli peppers contain more vitamin C than citrus fruits and fresh red chilli has more vitamin A than carrot. Chillies bright colour and less pungency are preferred in Europe and in the West. Chilli is commercially important for two qualities, *i.e.*, its red colour is due to the pigment capsanthin and its biting pungency is due to capsaicin. Among these alkaloids, capsaicin and dihydrocapsaicin are the major alkaloids that contribute up to 80 per cent of the total capsaicinoids. Though India is the leading producer, the average yield of chilli is very low (1.11 t/ha dry chilli) as compared to developed countries like USA, China, South Korea, Taiwan etc, where the average yield ranges from 3 to 4 t/ha. Low productivity in chilli is mainly attributed to lack, of high yielding, pest and disease resistant varieties or hybrids. Only about 2.60 percent chilli area is under hybrids in India, while in the countries like Korea and Taiwan more than 90 percent area is covered by Andhra Pradesh. There are more than 400 different varieties of chillies found all over the world and most popular among these are Sannam, 334, 273, Byadgi, Wonder Hot, Mundu, Teja, Yellow Chillies and Tomato Chillies.

Capsicum has been cultivated over centuries, producing both pungent and sweet fruits. *Capsicum annuum* L. is characterized by a wide variety of fruit size, shape and with different capscaicnoid content. Despite the importance of this plant as spice and its medicinal uses, research on its genetic variability and potential for breeding program is still incipient. There is also an urgent need to investigate the genetic control of some traits with the objective of introgressing these traits into cultivated varieties.

According to Directorate of Economics and Statistics of Andhra Pradesh 2014-2015 statistical data, it was cultivated in 1.35 lakh hectares and produced about 7.40 lakh tons of chilli with productivity of 5480 kg per hectare. Residual Andhra Pradesh is producing 1/4th of total Indian chilli and has got 1st place for its production. Guntur, in the South Indian state of Andhra Pradesh, produces 30% of national production. Chillies is cultivated mostly in Guntur (63000 ha), Prakasham (32000 ha), Kurnool (14000 ha) and Krishna (9000 ha) districts of Andhra Pradesh with production of Guntur (409000 tonnes), Prakasham (14900 tonnes), Kurnool (72000 tonnes) and Krishna (72000 tonnes) respectively, in large scale and 90% consumed by local population.

The worlds hottest chilli "Naga Jolokia" is cultivated in hilly terrain of Assam in a small town Tezpur, India. It is necessary to increase the chilli productivity to meet the demand of growing population. India has exporting chilli to USA, Canada, UK, Saudi Arabia, Singapore, Malaysia, Germany and many countries across the world. United States estimated chilli production is about 100 million pounds while 200 million pounds is consumed, leaving 100 million pounds to be imported and domestic production of chilli can increase with mechanical harvesting. Now-a-days, cost of cultivation of chilli is increased day by day due to indiscriminate use of inputs like seeds, fertilizers and pesticides and also scarcity of labour. The major harvest season is between December-March with supply reaching peak levels in February-April. Planting is held mainly during August-October. Chilli cultivation needs more number of labourers for harvesting apart from the usual field operations such as sowing, weeding, pesticide, snap the stem off, placing the Chillies in the plastic bucket. However, hand harvest is not a perfect system. Developed countries in agricultural sector like Unites States of America, Israel, etc. have introduced machinery for chilli harvest for their local environmental conditions. Chilli harvesters are not using in India due to variety of crop which requires number of picking throughout the entire life span of crop. The labour are available in India for harvesting of ripen chilli as compared to developed countries. The Indian farmers are unable to purchase the chilli harvester by investing of huge amount. It is harvested (picking) 2 to 4 times and these harvestings are within a short span of time to get the quality produce, otherwise market price of chilli will be reduced.

Farmer have to invest more money on harvest of chilli crop as it being a labour intensive operation and coincides with peak harvesting season of other crops and hot weather conditions are further increases cost on labour wages. While extensive harvest mechanization research has been conducted and commercial harvesters have been produced and used to varying extents in an assortment of chilli types, the New Mexico Chile Pepper Task Force and later the New Mexico Chile Association felt the loss of domestic production could only be addressed by fully mechanizing the industry. They petitioned for a systems approach to research that integrated plant breeding, production practices, harvest mechanization, post-harvest processing and agricultural economics and research has not been conducted in India on chilli harvest mechanization. Mechanization is only the way through appropriate technology need to be developed to make farmer as profitable as possible and reduce the cost of harvest.

MATERIAL AND METHODS

The base frame was designed to house the main components of the harvester and harvesting mechanism. All the components of chilli harvester attached to the base frame. From the collected data of morphological characteristics studies of chilli crop, the average height of the chilli plant at the time of harvesting was taken as bench mark. The base frame was fabricated with braces and brackets of M. S angular as shown in Plate 1. Cutting mechanism is very vital unit and complete success of the machine depends upon the efficiency of the mechanism. In this mechanism basic components are.

1. Double helical rollers
2. Transmission unit
3. Prime mover

The open inclined double helical rollers were designed by supporting on both the ends of shafts on base frame. To fabricate these rollers to rotate in the opposite direction to each other for producing cutting cum shearing action on the red chilli pod stem so as to harvest chilli from the plant. Since this helical knife were on peripheral orbit and mounted double helical roller shafts were subjected to both the twisting and bending moments due to rotational motion and self weight of the material.

When the shaft was subjected to combined twisting moment and bending moment, hence the shaft was designed on the basis of two moments simultaneously.

The following two theories were important from the subject point of view.

1. Maximum shear stress theory or Guest's theory which was used for ductile materials such as mild steel.
2. Maximum normal stress theory or Rankine's theory. It was used for brittle materials such as cast iron.

The expression $\frac{1}{2}[M + \sqrt{M^2 + T^2}]$ is known as equivalent bending moment and is denoted by M_e. The equivalent bending moment may be defined as that moment which when acting

By using the above equations, the mechanical properties of steel shafts were substituted to get the hollow mild steel shaft size. The twisting moment of hollow pipe can be alculated by using the following formula as follows,

Twisting moment (T) = $\frac{P \times 60}{2\pi N}$

Where,
P = power taken as 750 watts
N = rotational speed of the shaft taken as 1000 rpm
Calculated twisting moment (T) **= 8.0 N-m**

$$M_e = \frac{1}{2}[50 + \sqrt{50^2 + 8^2} = \frac{\pi}{32} \times 202(d_o)^3(1 - 0.96^4)$$

$$51 \times 10^3 = \frac{\pi}{32} \times 202(d_o)^3(1 - 0.96^4)$$

d_o = 25 mm

For hollow shafts,

The equivalent bending moment can be express as follows

$$M_e = \frac{1}{2}[M + \sqrt{M^2 + T^2} = \frac{\pi}{32} \times \sigma_b(d_o)^3(1 - K^4)$$

Where,
M = bending moment
T = twisting moment
σ_b = bending stress
d_o = outer dia. of hollow pipe
K = ratio of inner diameter to outer diameter of hollow pipe

The expression $\sqrt{M^2 + T^2}$] is known as equivalent twisting moment and is denoted by T_e. The equivalent twisting moment may be defined as that twisting moment, which when acting alone, produces the same shear stress as the actual twisting moment. By limiting the maximum shear stress equal to the allowable shear stress for the material.

The equivalent twisting moment can be express as follows

$$T_e = \sqrt{M^2 + T^2} = \frac{\pi}{16} \times \tau (d_o)^3 (1 - k^4)$$

Calculated size of hollow pipe for only carrying the self weight of the material (d_o)= 25 mm. But approximately same amount of the extra force coming from the chilli plants and acted on the hollow pipe while harvesting in the field. So it was selected a hollow pipe size around 5.0cm

The equivalent twisting moment (T_e) was calculated by using the equation (ii) as follows

$$T_e = \sqrt{50^2 + 8^2} = \frac{\pi}{16} \times 101(d_o)^3(1 - 0.96^4)$$

$$51 \times 10^3 = \frac{\pi}{16} \times 101(d_o)^3(1 - 0.96^4$$

d_o = 25 mm

The pipe size was calculated only based on the self weight of the material but forces also exerting from the chilli plants. The forces coming from the chilli plants were not constant The small size of 9 cm pulley was fixed to the electrical motor shaft and remaining large size pulleys were changed alternatively on the roller shaft and when the change is required to reduce the speed from 1440 rpm of electrical motor to required speed of speed of rollers. The details of pulleys were given in the Table 1. Four numbers of selected suitable V-belts were used based on the calculated length of V-belts. The pulley-1 of diameter 90 mm was fixed on the prime mover and the pulleys of different diameters were changed on the double helical rollers and details were given in Table 2. The fabricated chilli harvester for experimental set up was shown in the Plate 3.1. The chilli harvester with electrical motor used as a prime mover to operate double helical rollers. The chilli harvester was hitched to the high clearance tractor. The fabricated chilli harvester was shown in the Plate 1. The trough was designed on both sides of the double helical rollers on both sides made with mild steel sheet of thickness 3 mm. The trough is used for collect the harvested ripen chilli.

Power requirement

The input power required to operate the double helical rollers to harvest the ripen chilli in the field was calculated as followed for the followed data
1. The maximum rotational speed of double helical rollers = 1000 rpm
2. The maximum load exerted upon the rollers (self weight + External force) = 75 N
3. Diameter of each rollers = 15 cm
4. Overall mechanical efficiency = 75%

Power requirement as per the above data (kW) = Load (N) × speed (m. s^{-1})/1000

Input power of the prime mover = power/efficiency
Power requirement to operate the rollers = 100 × 7.85/1000

Power requirement to operate the rollers = 0.58875 kW

Calculated Input power = 0.58875/0.75 = **0.74 kW**

As per the calculated input power required to operate the double helical rollers, the prime mover should be above or around 1.0 HP (0.75 kW).

Pulleys

The power which was required to operate open inclined double helical rollers was taken from prime mover through pulleys and V-belt. To obtain different speeds of rollers in the range of 300 rpm to 700 rpm five numbers of pulleys with different sizes were selected as shown in the Table 1.

Table1. Different Sizes of pulleys

S.No	Name of the pulley	Diameter of the pulley (mm)	Speed of Rollers (RPM)
1	Pulley-1	90	Fixed on electrical motor
2	Pulley-2	170.5	740
3	Pulley-3	250	518
4	Pulley-4	300	432
5	Pulley-5	400	324

Table 2. Length of calculated V-belt

S.No	Diameter of Pulleys (cm)	Distance between centers 2-pulleys (cm)	Length of open V-belts (cm)
1	Pulley-2 = 17.50	56 cm	217
2	Pulley-3 = 25.00		231
3	Pulley-4 = 30.00		240
4	Pulley-5 = 40.00		260

Plate 1. Prototype ripen chilli harvester

Parts of Chilli Harvester

1. Crop Divider
2. Ground Wheel
3. Trough
4. Helical Rollers
5. Base Frame

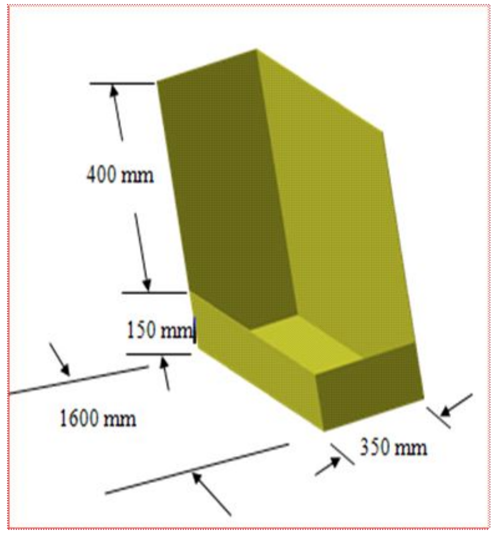

Figure 1. Trough

CONCLUSION

The prototype ripen chilli harvester was designed to be operated by PTO of the tractor. The power was transmitted from the high clearance tractor PTO to the double helical rollers by using the telescope universal joint. The morphological characteristics of chilli crop were collected from the different parts of the Guntur district to design the experimental unit for ripened chilli harvesting. The experimental unit was designed with two counter rotating double helical rollers of each length 2000 mm and overall diameter 140 mm. The base frame was developed with the height of 1000 mm, width of 850 mm and length of 1600 mm to house the double helical rollers and other components of harvester inside the base frame.

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